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Field Guide to the Canadian Forest Fire Behavior Prediction (FBP) System

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Field Guide to the Canadian Forest Fire Behavior Prediction (FBP) System

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While care has been taken to ensure that the charts and tables in this guide accurately reflect the Canadian Forest Fire Behavior Prediction System (1992) for the stated conditions, no assurance is given that the work is free from error or omission. The Canadian Forest Service and the authors disclaim all liability for the consequences of anything done, or omitted to be done, by a person relying on the information given. Use of this guide is at the reader's sole risk and discretion.

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Introduction

The Canadian Forest Fire Behavior Prediction (FBP) System is a systematic method for assessing wildland fire behavior potential. It is a series of mathematical equations relating fire characteristics to wind, fuel moisture, and topographic conditions for 16 benchmark fuel (vegetation) types. Complete and precise fire behavior predictions are best made using computer-based representations of the system. However, this guide was prepared to allow first approximations of FBP System outputs when computer-based applications are not available. It is intended mainly to be used as a field reference and should be used in place of the forest fire growth calculator (McAlpine 1986), which is based on the interim version of the FBP System (Alexander et al. 1984). Certain simplifications were made so that important fire behavior characteristics could be presented in tabular form, and these are noted in the appropriate section. The symbols used in the guide are listed in Appendix 1 and many of the terms are defined in Appendix 2.

A complete technical description of the FBP System is given in Info. Rep. ST-X-3 Development and structure of the Canadian Forest Fire Behavior Prediction System (Forestry Canada Fire Danger Group 1992). Guidance on its application is given in the Canadian Forest Fire Behavior Prediction System User Guide (Hirsch 1996). Fire suppression interpretations based on head fire intensity class are also available for several fuel types (Alexander and De Groot 1988; Alexander and Lanoville 1989; Alexander and Cole 1995).

Caution

Fire behavior predictions are intended to assist in decision-making, and are not a substitute for experience, sound judgement, or observation of actual fire behavior. This document is not intended to be a guide to safe working conditions; almost any fire can be hazardous in some circumstances. Fire behavior can change rapidly due to changes in fuel conditions, slope, and exposure to wind. Because no system can ever fully account for all of the variables that affect fire behavior, operational personnel must be aware of the limitations of the system and be able to recognize unique or unusual situations.

Assumptions

Users must be careful not to apply the system beyond its useful range. In the FBP System, predictions are limited to a fire spreading during one burning period from a single point or line, assuming that:

- fuels conditions are similiar to one of the 16 benchmark fuel types.
- the fuel moisture codes used are representative of the site conditions.
- fuels are uniform and continuous, topography is simple and homegenous, and wind is constant and uni-directional.
- the fire is wind or wind/slope driven, and spread is not affected by a convection column. Wind is represented by the 10 m open wind.
- the fire is unaffected by suppression activities (free burning).
- a fire starting from a point source will have an elliptical shape under the above conditions.
- the effect of firebrands on spread is accounted for.

Use of the Guide

The following steps form the procedure for use of the guide:

1. Select the most appropriate **fuel type** (Table 1). In choosing a fuel model, the physical properties of the fuel complex such as surface fuel conditions, stand density, and crown-base height should be considered in addition to the tree species composition. Examples of the fuel types are given in Appendix 3.

2. Determine the most representative **Fine Fuel Moisture Code (FFMC)**. The **hourly FFMC** should be used, if available. Alternatively, the **diurnal FFMC** (Tables A.1-A.2, Appendix 5) may be used. The **daily standard FFMC** may be used to represent conditions at 1600 LST. The FFMC for slash and open fuel types may be further adjusted for topographic effects on clear days during the months of March, April, August, September, or October between 1200-2000 LST (Table A.3, Appendix 5).

3. Estimate the slope and determine the **slope equivalent wind speed** for the selected fuel type (Table 2). If the slope is ≥ 50% and FFMC is ≥ 95, add 5 to the table value.

4. Determine the on-site wind speed (measured, estimated, or forecast). Appendix 4 (Beaufort Scale) may be used as a guide if instruments are not available. If the wind is blowing upslope, **add** the observed wind speed to the slope equivalent wind speed. If the wind is blowing downslope, **subtract** the slope equivalent wind speed from the the observed wind speed. The result is the **effective wind speed**. Cross-slope fire spread results if the wind is blowing across the slope. However the cross-slope spread rate and direction are determined through vector addition, which is beyond the scope of this guide.

5. Find the **Initial Spread Index (ISI)** from FFMC and the effective wind speed (Table 3). Also, note the back fire initial spread index (**BISI**) if greater than zero.

6. Determine the **Buildup Index (BUI)** for the prediction point from the closest representative fire weather station. Find the **equilibrium head fire rate of spread (ROS)** and the **back fire rate of spread (BROS)** for the selected fuel type (Tables 4.1-4.26) from the ISI/BISI and BUI. The **type of fire** is indicated in the tables as follows:

black figures	surface fire	< 10 % crown fraction burned
black figures with *	intermittent crown fire	10 - 89 % crown fraction burned
white figures	continuous crown fire	>90 % crown fraction burned

The line dividing the intermittent crown fire class is the 50% crown fraction burned (CFB) level. The background shading in the charts indicates the fire intensity class. BUI_0 (the BUI value that has no effect on ROS) is also indicated and can be used if the BUI is not known.

7. **Head fire spread distance** and **back fire spread distance** for various prediction intervals can be determined from the equilibrium ROS or BROS using Table 5.1 or 5.2. Distances are given for three spread functions:
   Equilibrium ROS in all fuel types
   Accelerating ROS in open fuel types and surface fires in closed fuel types
   Accelerating ROS in crown fires in closed fuel types
   Use the spread values based on the equilibrium ROS for fires spreading from an active perimeter. Use the spread values with an acceleration adjustment for fires spreading from a point source.

8. **Fire size** and **perimeter length** of a fire starting from a point source can be estimated for a given time period from the total spread distance and effective wind speed (Table 6.1 or 6.2). The **perimeter growth rate** can be determined from ROS and effective wind speed in Table 7.1 or 7.2. Values are given for both timber/slash and grass fuel types. Fire width can be estimated by dividing the total spread distance by the length/breadth (L/B) ratio (Table 6.1 or 6.2).

Accuracy of the Guide

This guide will give a good estimate of the Fire Intensity Class and Type of Fire in most cases. In most fuel types users should be able to estimate fire size characteristics within ± 20% of computed values for ROS > 3.
Fire characteristics are less accurate for the 0-20 BUI class and for ROS ≤ 3 in because of interpolation and rounding errors.

Procedures used in the guide

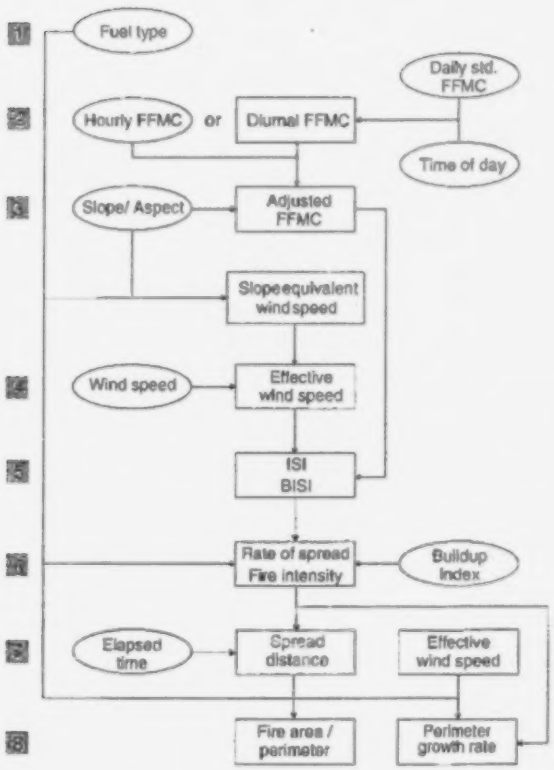


TABLE 1
FBP System

Fuel types

Group	Identifier	Description
Coniferous	C-1	Spruce-lichen woodland
	C-2	Boreal spruce
	C-3	Mature jack or lodgepole pine
	C-4	Immature jack or lodgepole pine
	C-5	Red and white pine
	C-6	Conifer plantation
	C-7	Ponderosa pine-Douglas-fir
Deciduous	D-1	Leafless aspen
Mixedwood*	M-1	Boreal mixedwood-leafless
	M-2	Boreal mixedwood-green
	M-3	Dead balsam fir mixedwood-leafless
	M-4	Dead balsam fir mixedwood-green
Slash	S-1	Jack or lodgepole pine slash
	S-2	White spruce-balsam slash
	S-3	Coastal cedar-hemlock-Douglas-fir slash
Open	O-1a	Matted grass
	O-1b	Standing grass

* M-1 and M-2 are transitional between C-2 and D-1

TABLE 2

Slope equivalent wind speed (km/h)

Fuel type identifier	Slope (%)					
	10	20	30	40	50	60
C-1	1	3	4	6	8	10
C-2	3	7	12	17	23	29
C-3	2	4	6	9	12	15
C-4	3	7	12	17	23	29
C-5	1	3	5	7	9	12
C-6	2	4	7	10	13	17
C-7	2	5	9	13	17	21
D-1	3	7	11	16	21	26
M-1	3	7	12	16	22	28
M-2	3	7	11	16	21	26
M-3 30PDF	3	7	11	16	21	26
60PDF	3	8	13	18	24	32
100PDF	4	9	14	21	29	41
M-4 30PDF	2	5	8	11	14	18
60PDF	2	6	9	13	18	23
100PDF	3	8	13	18	25	32
S-1	4	8	14	20	27	35
S-2	3	7	11	16	21	26
S-3	2	4	6	9	12	16
O-1a	3	8	13	19	25	32
O-1b	3	7	11	15	21	26

Find the fuel type identifier, then move horizontally to the most appropriate slope column to read the **slope equivalent wind speed**. If the FFMC ≥ 95 and slope ≥ 50% add 5 to the table value.

Slope equivalent windspeed varies with FFMC. Those given above are for FFMC 90 and are accurate to ± 2 km/h of the true values for FFMC 80-96. The values for FFMC ≥ 95 and slope ≥ 50% may be under estimated by ≥ 5 km/h.

M-1 and M-2 values are for 50:50 conifer / hardwood. M-3 and M-4 modifiers are percent dead fir (PDF).

TABLE 3

ISI/BISI Initial Spread Index
Back fire Initial Spread Index

Effective wind speed (km/h)

FFMC	0	5	10	15	20	25	30	35	40	45	50
78	1	1	2	2	3	3	4	5	7	8	9
	1	1	1	0	0	0	0	0	0	0	0
80	1	1	2	2	3	4	5	7	9	10	11
	1	1	1	1	0	0	0	0	0	0	0
82	1	2	2	3	4	5	6	8	11	13	14
	1	1	1	1	1	0	0	0	0	0	0
84	2	2	3	4	5	6	8	11	14	17	18
	2	1	1	1	1	1	0	0	0	0	0
86	2	3	4	5	7	9	11	14	18	22	24
	2	2	1	1	1	1	1	0	0	0	0
88	3	4	5	7	9	11	15	19	24	29	32
	3	3	2	2	1	1	1	1	0	0	0
90	4	6	7	9	12	15	19	25	32	39	43
	4	3	3	2	2	1	1	1	1	0	0
92	6	7	9	12	16	20	26	33	43	51	57
	6	4	3	3	2	2	1	1	1	1	0
94	8	10	12	16	21	27	34	44	57	66	76
	8	6	5	4	3	2	2	1	1	1	1
96	10	13	16	21	27	35	45	58	74	89	99
	10	8	6	5	4	3	2	2	1	1	1
98	13	17	21	28	36	46	59	76	97	117	130
	13	10	8	6	5	4	3	2	2	1	1

Red figures are ISI

Black figures are BISI

TABLE 2

Slope equivalent wind speed (km/h)

Fuel type identifier	Slope (%)					
	10	20	30	40	50	60
C-1	1	3	4	6	8	10
C-2	3	7	12	17	23	29
C-3	2	4	6	9	12	15
C-4	3	7	12	17	23	29
C-5	1	3	5	7	9	12
C-6	2	4	7	10	13	17
C-7	2	5	9	13	17	21
D-1	3	7	11	16	21	26
M-1	3	7	12	16	22	28
M-2	3	7	11	16	21	26
M-3 30PDF	3	7	11	16	21	26
60PDF	3	8	13	18	24	32
100PDF	4	9	14	21	29	41
M-4 30PDF	2	5	8	11	14	18
60PDF	2	6	9	13	18	23
100PDF	3	8	13	18	25	33
S-1	4	8	14	20	27	35
S-2	3	7	11	16	21	28
S-3	2	4	6	9	12	16
O-1a	3	8	13	19	26	33
O-1b	3	7	11	15	21	26

slope equivalent wind speed

TABLE 3

ISI/BISI Initial Spread Index
Back fire Initial Spread Index

TABLE 4.1
Equilibrium rate of spread (m/min) and fire intensity class

C-1 Spruce-lichen woodland

INTENSITY CLASS

	1	< 10 kW/m
	2	10 – 500
	3	500 – 2 000
	4	2 000 – 4 000
	5	4 000 – 10 000
	6	> 10 000

ISI \ BUI	0	21	31	41	61	81	121	161
	20	30	40	60	80	120	160	200
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19	12	17	18	19	19	20	20	20
20	14	19	20	21	21	22	22	22
21-25	18	25	27	28	29	29	30	30
26-30	26	35	38	39	40	41	42	42
31-35	33	45	48	50	51	52	53	54
36-40	39	53	56	59	60	62	63	63
41-45	44	59	63	66	68	69	70	71
46-50	50	64	68	71	73	75	76	77
51-55	51	68	72	75	78	79	81	81
56-60	52	71	75	78	81	83	84	85
61-65	54	73	77	81	83	85	86	87
66-70	55	75	79	83	85	87	88	89

Constants: foliar moisture content= 97%; CBH = 2m; surface fuel consumption for FFMC 90
Type of fire: **surface** **intermittent crown*** **continuous crown** _ CFB 50% BUI$_0$

TABLE 4.2
Equilibrium rate of spread (m/min) and fire intensity class

C-2 boreal spruce

INTENSITY CLASS
1 < 10 kW/m
2 10 – 500
3 500 – 2 000
4 2 000 – 4 000
5 4 000 – 10 000
6 > 10 000

	BUI 0	21	31	41	61	81	121	161
ISI	20	30	40	60	80	120	160	200
1					2			
2					3			
3								
4					4			
5								
6					5			
7								
8						11	12	12
9				11*	12	13	14	14
10			11*	12	14	15	16	16
11		10*	12	14	16	17	18	18
12		11*	14	16	17	19	20	20
13		12	15	17	19	21	22	22
14		13	16	19	21	23	24	25
15		15	18	21	6 23	25	26	27
16		16	19	22	25	27	28	29
17		17	21	24	27	29	30	31
18		18	22	26	28	31	32	33
19		19	23	27	30	33	34	35
20		20	25	29	32	34	36	37
21-25	8*	24	29	34	37	40	42	43
26-30	10*	29	35	41	46	49	52	53
31-35	12*	34	41	48	53	57	60	62
36-40	14*	39	47	54	60	65	68	70
41-45	15	43	52	60	66	72	75	78
46-50	16	46	56	65	72	78	82	84
51-55	17	49	60	70	77	83	87	90
56-60	18	52	64	74	82	88	92	95
61-65	19	55	67	77	85	92	97	100
66-70	20	57	69	80	89	96	101	104

Constants: foliar moisture content = 97% ; crown base height = 3m
Type of fire: **surface** **intermittent crown*** **continuous crown** _CFB 50% BUI$_0$

TABLE 11

Equilibrium rate of spread (m/min) and fire intensity class

C-1 Spruce-lichen woodland

TABLE 1.2
Equilibrium rate of spread (m/min) and fire intensity class

C-2 boreal spruce

				2	0.6	0.6	0.6
		1	1	3	1	2*	2*	2*
	2	2	2*		3*	3*	3*	3*
	3	3*	4*	4	4*	4*	4*	5*
	3*	4*	5*		5*	6*	6*	6*
	4*	5*	6*	5	7*	7*	8*	8*
	5*	7*	8*		9*	9*	10*	10*
	7*	8*	9*		10*			
	8*	9*	11*					
3	9*	11*						
4	10*							
4	11*							
4								
5								
5				6				
6*								
6*								
6*								
7*								
7*								
8*								
10*								
12*								
14*								

surface intermittent crown*

TABLE 4.3
Equilibrium rate of spread (m/min) and fire intensity class

C-3 mature jack or lodgepole pine

INTENSITY CLASS
1 < 10 kW/m
2 10 – 500
3 500 – 2 000
4 2 000 – 4 000
5 4 000 – 10 000
6 > 10 000

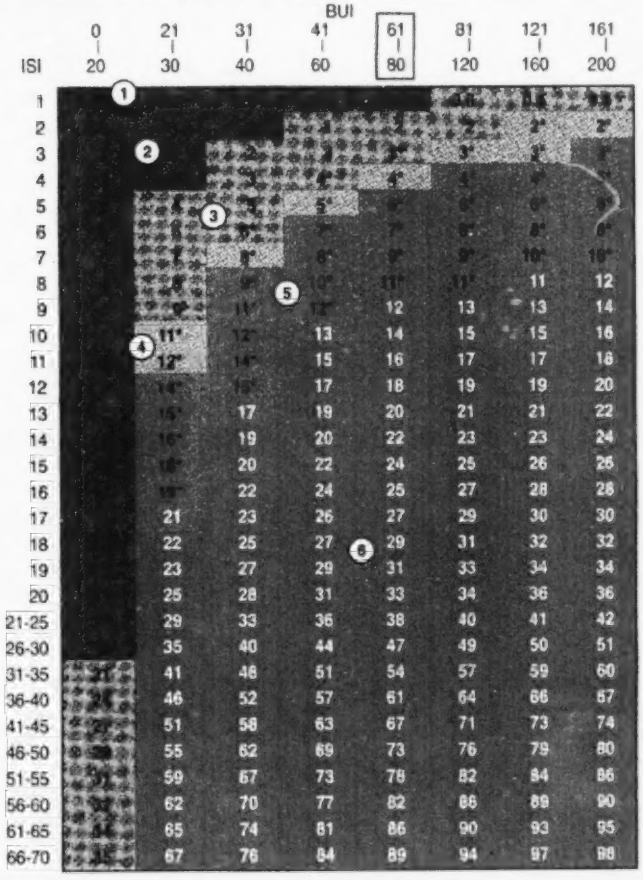
ISI	BUI 0 (20)	21 (30)	31 (40)	41 (60)	61 (80)	81 (120)	121 (160)	161 (200)
1					1			
2					2			
3							0.5	0.5
4					0.5	0.5	1	1
5				1	1	1	2	2
6				1	2	2	2	2
7			2	2	3	3	4	4
8			3	3	4	4	5	5
9			4	4	5	5	6	6
10		6	5	6	7	7	7	7
11		7	7	7	8	8	9	9
12		8	8	9	10	10	11	11
13		9	9	10	11	12	12	13
14		10	11	12	13	14	14	15
15		11	12	13	14	16	16	17
16		12	14	15	16	17	18	19
17		14	15	17	18	19	21	21
18		15	17	19	20	21	23	24
19		16	19	21	22	23	26	26
20		18	21	23	25	26	28	29
21-25		21	27	30	31	33	34	36
26-30		33	38	41	43	45	46	48
31-35		42	47	51	55	57	58	60
36-40	43	50	56	61	65	68	69	71
41-45	49	57	64	70	74	77	79	81
46-50	54	63	71	77	82	86	88	90
51-55	58	69	77	84	89	93	95	97
56-60	62	73	82	89	95	99	101	103
61-65	65	77	86	94	100	104	106	108
66-70	68	80	90	97	103	108	110	112

Constants: foliar moisture content =97% ; crown base height = 8m
Type of fire: **surface** **intermittent crown*** **continuous crown** _ CFB 50% BUI$_0$

TABLE 4.4
Equilibrium rate of spread (m/min) and fire intensity class

C-4 immature jack or lodgepole pine

INTENSITY CLASS
1 < 10 kW/m
2 10 – 500
3 500 – 2 000
4 2 000 – 4 000
5 4 000 – 10 000
6 > 10 000



Constants: foliar moisture content = 97%; crown base height = 4m
Type of fire: **surface** **intermittent crown*** **continuous crown** CFB 50% BUI_0

TABLE 4.3
Equilibrium rate of spread (metres)
and fire intensity class

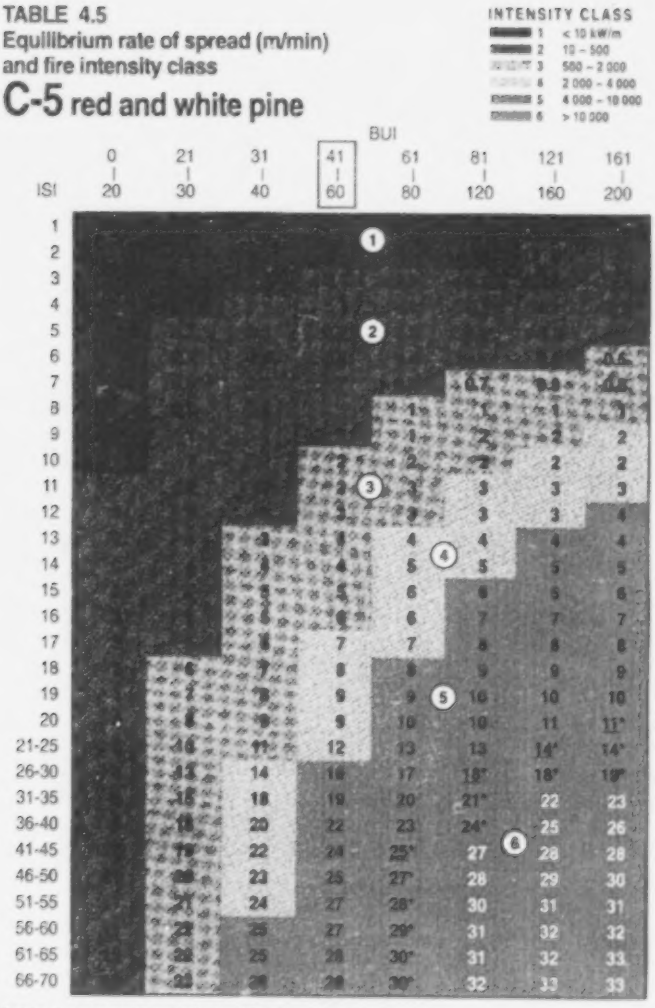
C-3 mature jack or lodgepole pine

TABLE 4.1
Equilibrium rate of spread (m/min)
and fire intensity class

C-4 immature jack or lodgepole pine

TABLE 4.5
Equilibrium rate of spread (m/min) and fire intensity class

C-5 red and white pine



Constants: foliar moisture content = 97% ; crown base height = 18m
Type of fire: **surface** **intermittent crown*** **continuous crown** _ CFB 50% BUI$_0$

TABLE 4.6
Equilibrium rate of spread (m/min) and fire intensity class

C-6 conifer plantation

7 m crown base height

INTENSITY CLASS
1 < 10 kW/m
2 10 – 500
3 500 – 2 000
4 2 000 – 4 000
5 4 000 – 10 000
6 > 10 000

ISI	BUI 0	21	31	41	61	81	121	161
	20	30	40	60	80	120	160	200
1								
2								
3								
4								
5								
6								2
7						3	3	4
8						3	6	7
9					4	7	10	11
10					5	11	15	15
11						15	18	19
12				7	13	19	21	22
13				8	17	22	24	24
14				9	21	25	26	27
15				10	24	28	29	29
16				18	27	30	31	31
17				20	30	32	33	33
18				24	32	34	34	34
19			13	28	34	35	36	36
20			13	30	36	37	37	37
21-25			16	37	40	40	40	41
26-30			22	43	45	45	45	45
31-35			34	47	48	48	48	48
36-40			41	50	51	51	51	51
41-45			45	52	53	53	53	53
46-50			48	54	54	54	54	54
51-55			50	55	56	56	56	56
56-60			51	56	57	57	57	57
61-65			52	57	57	57	57	57
66-70			53	58	58	58	58	58

Constants: foliar moisture content = 97%; crown base height = 7m
Type of fire: **surface** **intermittent crown*** continuous crown _ CFB 50% BUI$_0$

TABLE 15
Equilibrium rate of spread (chains/h) and fire intensity class

C-5 red and white pine

TABLE 8.5

Equilibrium rate of spread (m/min) and fire intensity class

C-6 conifer plantation

7 m crown base height

				0.7	0.7	0.7
			1	1	1	1
			2	2	2	2
		2	2	3	3	4
		3	3	3	6*	7*
	4	4	4	7*	10*	11*
	4	5	5	11*	14*	15*
	5	6	6	15*	18*	19*
	6	7	13*	19*	21*	22*
5*	7	8	17*	22*	24*	24*
7	8	9	21*	25*	26*	27*
8	9	10	24*	28*	29*	29*
9	10	18*	27*	30*	31*	
10	11	20*	30*	32*		
10	12	24*	32*			
11	13	28*	34*			
12	13	30*	35*			
14	16	37*				
17	22*					
19	34*					
20	41*					
21	45*					
22	48*					
22	50*					
23	51*					
23	52*					
23	53*					

TABLE 4.7
Equilibrium rate of spread (m/min) and fire intensity class

C-6 conifer plantation

2 m crown base height

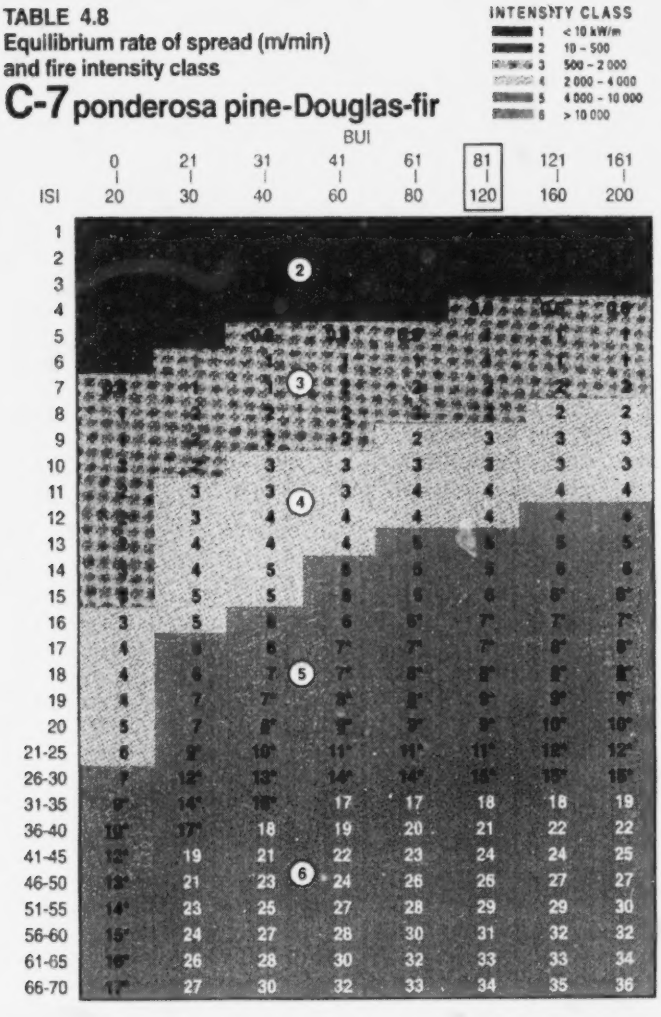
INTENSITY CLASS
1 < 10 kW/m
2 10 – 500
3 500 – 2 000
4 2 000 – 4 000
5 4 000 – 10 000
6 > 10 000

ISI \ BUI	0	21	31	41	**61**	81	121	161
	20	30	40	60	**80**	120	160	200
1	1							
2				2				
3								
4								
5								
6				3				
7								
8				4				
9				5				
10			10*					
11								
12								
13		11*						
14		15*						
15						30	30	30
16					31	31	32	32
17				32	33	33	33	33
18				34	6 34	35	35	35
19				35	36	36	36	36
20			36	37	37	37	37	37
21-25		37	40	40	40	41	41	41
26-30		43	44	45	45	45	45	45
31-35		47	48	48	48	48	48	48
36-40		50	51	51	51	51	51	51
41-45		52	53	53	53	53	53	53
46-50		54	54	54	54	54	54	54
51-55		55	56	56	56	56	56	56
56-60		56	56	57	57	57	57	57
61-65		57	57	57	57	57	57	57
66-70		57	58	58	58	58	58	58

Constants: foliar moisture content = 97%; crown base height = 2m
Type of fire: **surface** **intermittent crown*** **continuous crown** _ CFB 50% BUI$_0$

TABLE 4.8
Equilibrium rate of spread (m/min) and fire intensity class

C-7 ponderosa pine-Douglas-fir



Constants: foliar moisture content = 97% ; CBH = 10m; surface fuel consumption for FFMC 90
Type of fire: **surface** **intermittent crown*** **continuous crown** _ CFB 50% BUI$_0$

TABLE 17
Equilibrium rate of spread (m/min) and fire intensity class

C-6 conifer plantation

2 m crown base height

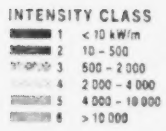
TABLE 4.8
Equilibrium rate of spread (m/min) and fire intensity class

C-7 ponderosa pine-Douglas-fir

							0.6	0.6	0.9
			0.8	0.8	0.9	1	1	1
		1	1	1	1	1	1	1
	0.8	1	1	2	2	2	2	2
	1	2	2	2	2	2	2	2
	1	2	2	2	2	3	3	3
	2	2	3	3	3	3	3	3
	2	3	3	3	4	4	4	4
	2	3	4	4	4	4	4	4
	2	4	4	4	5	5	5	5
	3	4	5	5	5	5	6	6
	3	5	5	6	6	6	6*	6*
	3	5	6	6	6*	7*	7*	7*
	4	6	6	7*	7*	7*	8*	8*
	4	6	7	7*	8*	8*	8*	8*
	4	7	7*	8*	8*	9*	9*	9*
	5	7	8*	9*	9*	9*	10*	10*
	6	8*	10*	11*	11*	11*	12*	12*
	7	12*	13*	14*	14*	15*	15*	15*
	9*	14*	16*					
	10*	17*						
	12*							
	13*							
	14*							
	15*							
	16*							
	17*							

TABLE 4.9
Equilibrium rate of spread (m/min) and fire intensity class

D-1 leafless aspen



ISI	BUI 0	21	31	41	61	81	121	161
	20	30	40	60	80	120	160	200
1	1							
2				2				
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14				3				
15								
16								
17								
18								
19								
20								
21-25								
26-30					4			
31-35								
36-40								
41-45								
46-50								
51-55						5		
56-60								
61-65								
66-70							6	

Note: crown fires are not expected in deciduous fuel types
Type of fire: **surface** BUI$_0$

TABLE 4.10
Equilibrium rate of spread (m/min) and fire intensity class

M-1 boreal mixedwood-leafless

75% conifer / 25% hardwood

INTENSITY CLASS

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI \ BUI	0 – 20	21 – 30	31 – 40	41 – 60	61 – 80	81 – 120	121 – 160	161 – 200
1								0.5*
2		2						
3							2	2
4		3			3	3*	3*	4*
5				4	4*	5*	5*	5*
6		5		5*	6*	6*	6*	6*
7		6*		7*	7*	7*	8*	8*
8		6	7*	8*	8*	9*	9*	9*
9		7	8*	9*	10*	10*	11*	11*
10		9*	10*	11*	11*	12*	12*	13
11		10*	11*	12*	13*	13	14	14
12		11*	12*	14*	14	15	16	16
13		12*	14*	15	16	17	17	18
14		13*	15*	16	17	18	19	19
15		14*	16	18	19	20	21	21
16		15*	18	19	20	21	22	23
17		17*	19	21	22	23	24	24
18		18	20	22	24	25	25	26
19		19	21	24	25	26	27	28
20		20	23	25	27	28	29	29
21-25		23	26	29	31	32	34	34
26-30	15	29	32	36	38	40	41	42
31-35	18*	34	38	42	44	47	48	49
36-40	20*	38	43	47	50	53	54	55
41-45	22*	42	48	52	56	58	60	61
46-50	24*	46	52	57	60	63	65	67
51-55	26	49	55	61	65	68	70	71
56-60	27	52	59	64	69	72	74	75
61-65	28	54	62	68	72	75	78	79
66-70	30	57	64	70	75	79	81	82

Constants: foliar moisture content = 97%; crown base height = 6m

Type of fire: **surface** **intermittent crown*** continuous crown CFB 50% BUI$_0$

TABLE 4.7
Equilibrium rate of spread (romin) and fire intensity class

D-1 leafless aspen

TABLE 4.10
Equilibrium rate of spread (m/min)
and fire intensity class

M-1 boreal mixedwood-leafless

75% conifer / 25% hardwood

							0.5
			1	1	1	1	1
		2	2	2	2	2	2
	2	3	3	3	3*	3*	4*
	3	4	4	4*	5*	5*	5*
	4	5	5*	6*	6*	6*	6*
	5	6*	7*	7*	7*	8*	8*
	6	7*	8*	8*	9*	9*	9*
4	7	8*	9*	10*	10*	11*	11*
4	9*	10*	11*	11*	12*	12*	
5	10*	11*	12*	13*			
6	11*	12*	14*				
6	12*	14*					
7	13*	15*					
7	14*						
8	15*						
9	17*						
9							
10							
10							
12							
15							
18*							
20*							
22*							
24*							

TABLE 4.11
Equilibrium rate of spread (m/min) and fire intensity class

M-1 boreal mixedwood - leafless

50% conifer / 50% hardwood

INTENSITY CLASS

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI 0	21	31	41	61	81	121	161
	20	30	40	60	80	120	160	200
1								
2								
3								
4							3	3
5						3	4*	4*
6					4	4*	5*	5*
7				5	5*	5*	6*	6*
8				6*	6*	7*	7*	7*
9			6	7*	7*	8*	8*	8*
10			7*	8*	8*	9*	9*	9*
11			8*	9*	10*	10*	10*	11*
12		8	9*	10*	11*	11*	12*	12*
13		9	10*	11*	12*	12*	13*	13
14		10*	11*	12*	13*	14	14	14
15		11*	12*	13*	14	15	15	16
16		12*	13*	14*	15	16	17	17
17		12*	14*	15	16	17	18	18
18	7	13*	15*	17	18	18	19	19
19	7	14*	16*	18	19	20	20	21
20	8	15*	17	19	20	21	22	22
21-25	9	16*	20	22	23	24	25	26
26-30	11	22	24	27	29	30	31	31
31-35	13	25	29	32	34	35	36	37
36-40	15	29	33	36	38	40	41	42
41-45	17	32	36	40	42	44	46	47
46-50	18	35	39	43	46	48	50	51
51-55	19*	37	42	46	49	52	53	54
56-60	21*	40	45	49	52	55	57	58
61-65	22*	42	47	52	55	58	59	60
66-70	23*	43	49	54	57	60	62	63

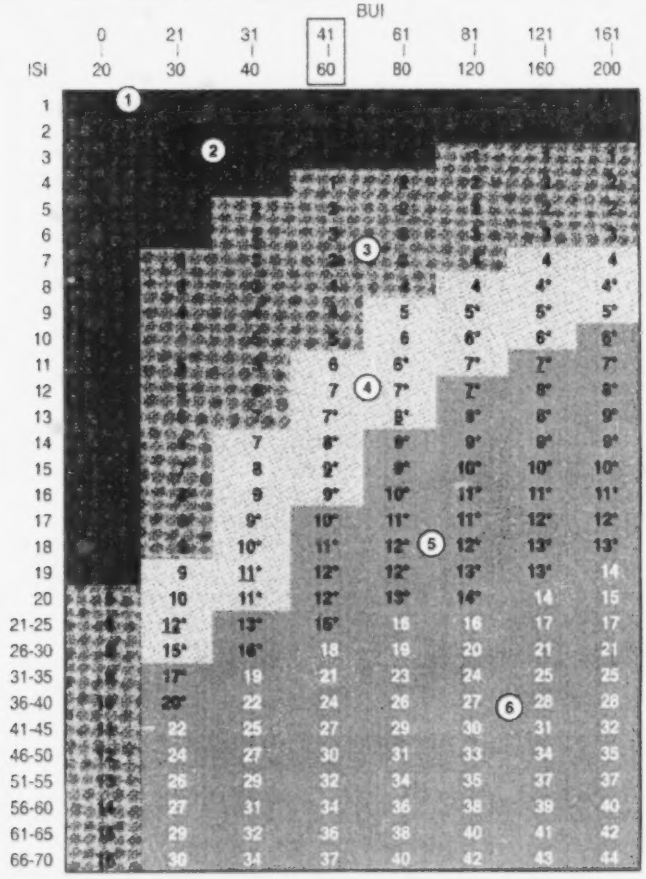
Constants: foliar moisture content = 97%; crown base height = 6m

Type of fire: **surface** **intermittent crown*** **continuous crown** _ CFB 50% BUI$_0$

TABLE 4.12
Equilibrium rate of spread (m/min) and fire intensity class

M-1 boreal mixedwood - leafless
25% conifer / 75% hardwood

INTENSITY CLASS
1 < 10 kW/m
2 10 – 500
3 500 – 2 000
4 2 000 – 4 000
5 4 000 – 10 000
6 > 10 000



Constants: foliar moisture content = 97%, crown base height = 6m
Type of fire: surface intermittent crown* continuous crown _ CFB 50% BUI$_0$

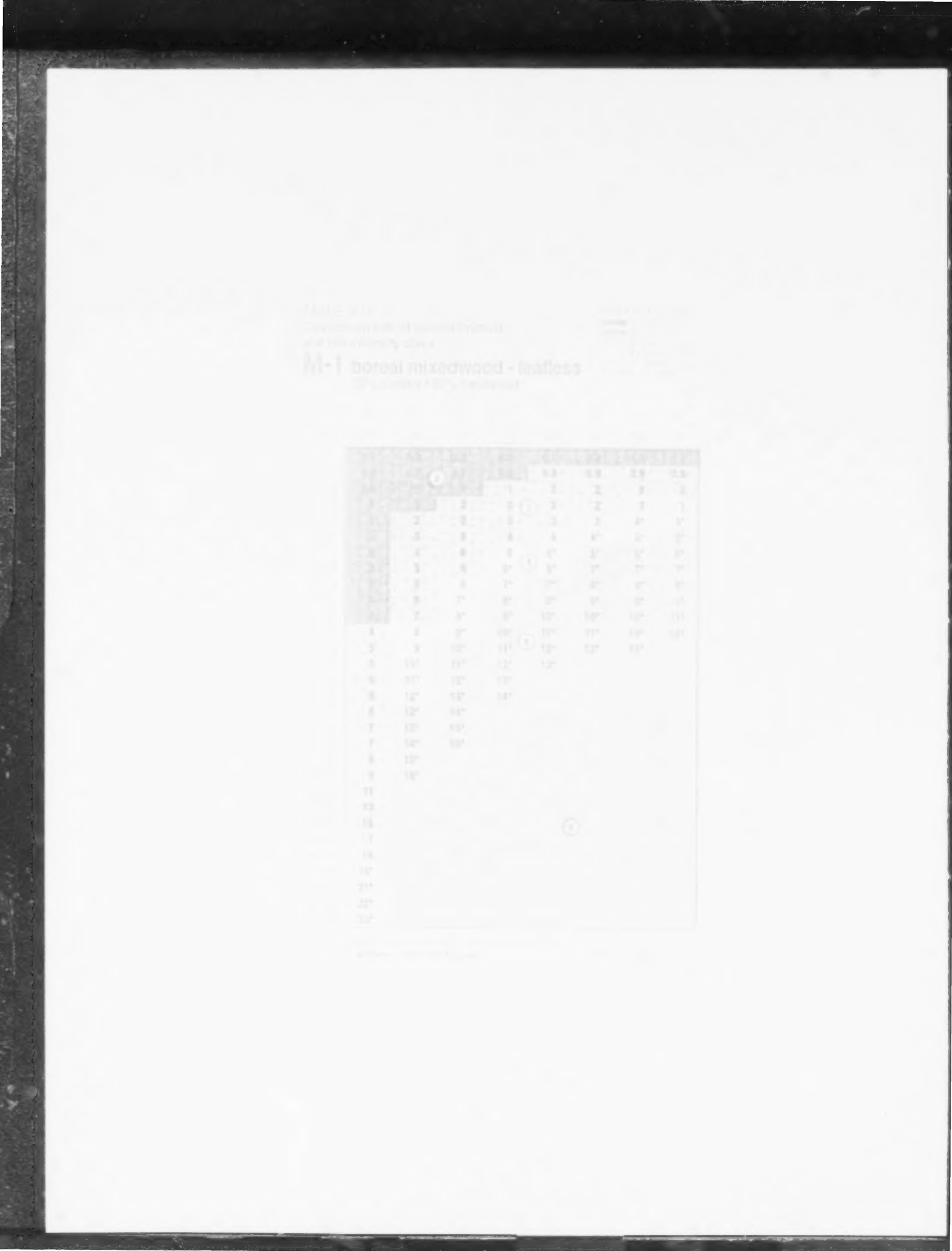


TABLE 4.13
Equilibrium rate of spread (m/min)
and fire intensity class

M-2 boreal mixedwood - green

75% conifer / 25% hardwood

INTENSITY CLASS

	1	< 10 kW/m
	2	10 – 500
	3	500 – 2 000
	4	2 000 – 4 000
	5	4 000 – 10 000
	6	> 10 000

ISI \ BUI	0	21	31	41	61	81	121	161
	20	30	40	60	80	120	160	200
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21-25								
26-30								
31-35								
36-40								
41-45								
46-50								
51-55								
56-60								
61-65								
66-70								

Constants: foliar moisture content = 97%, crown base height = 6m

Type of fire: **surface** | **intermittent crown*** | **continuous crown** | _ CFB 50% | BUI₀

TABLE 4.14
Equilibrium rate of spread (m/min) and fire intensity class

M-2 boreal mixedwood-green

50% conifer / 50% hardwood

INTENSITY CLASS

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI \ BUI	0	21	31	41	61	81	121	161
	20	30	40	60	80	120	160	200
1								
2		2						
3								
4								2
5			3			3	3	3
6					4	4*	4*	4*
7				4	4*	5*	5*	5*
8				5	6*	6*	6*	6*
9				6*	6*	7*	7*	7*
10			6	7*	7*	8*	8*	8*
11			7*	8*	8*	9*	9*	9*
12			8*	9*	9*	10*	10*	10*
13		8	9*	10*	10*	11*	11*	11*
14		9	10*	11*	11*	12*	12*	12*
15		9*	11*	12*	12*	13*	13	14
16		10*	11*	13*	13*	14	14	15
17		11*	12*	13*	14	15	16	16
18		12*	13*	14*	15	16	17	17
19		12*	14*	15	16	17	18	18
20		13*	15*	16	17	18	19	19
21-25		15*	17	19	20	21	22	22
26-30		19*	21	23	25	26	27	27
31-35		22	25	27	29	30	31	32
36-40		25	28	31	33	34	35	36
41-45		27	31	34	36	38	39	40
46-50		30	34	37	39	41	42	43
51-55	17	32	36	39	42	44	45	46
56-60	18	34	38	42	44	47	48	49
61-65	18	35	40	44	47	49	50	51
66-70	19*	37	41	46	48	51	52	53

Constants: foliar moisture content = 97%, crown base height = 6m

Type of fire: **surface** **intermittent crown*** continuous crown _ CFB 50% BUI_0

TABLE 3.14
Equilibrium rate of spread (ft/min) and fire intensity class

M-2 boreal mixedwood - green

50% conifer / 50% hardwood

					1	1	1	1
				1*	1	1	2	2
			2	2*	2	2	2	2
		2	2	3	3	3	3	3
		3	3	4	4	4*	4*	4*
		3	4	4	5*	5*	5*	5*
		4	5	5	6*	6*	6*	6*
		5	6	6*	6*	7*	7*	7*
		6	6	7*	7*	8*	8*	8*
		6	7*	8*	8*	9*	9*	9*
		7	8*	8*	9*	10*	10*	10*
	4	8	9*	10*	10*	11*	11*	11*
	4	9	10*	11*	11*	12*	12*	12*
	5	9*	11*	12*	12*	13*		
	5	10*	11*	13*	13*			
	6	11*	12*	13*				
	6	12*	13*	14*				
	6	12*	14*					
	7	13*	15*					
	8	15*						
	10	19*						
	11*							
	13							
	14							
	15							
	17							
	18							
	18							
	19*							

TABLE 4.15

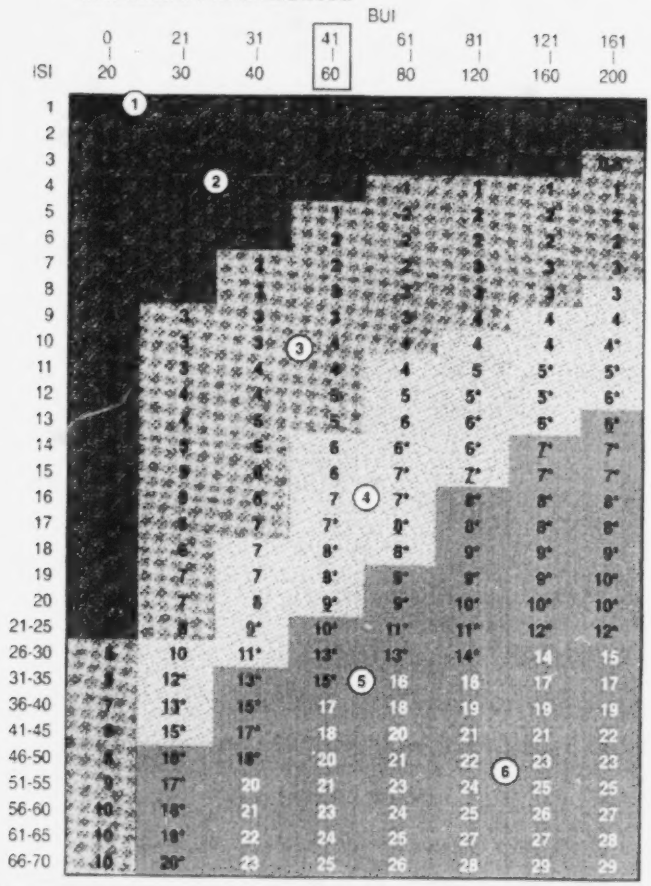
Equilibrium rate of spread (m/min) and fire intensity class

M-2 boreal mixedwood-green

25% conifer / 75% hardwood

INTENSITY CLASS

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000



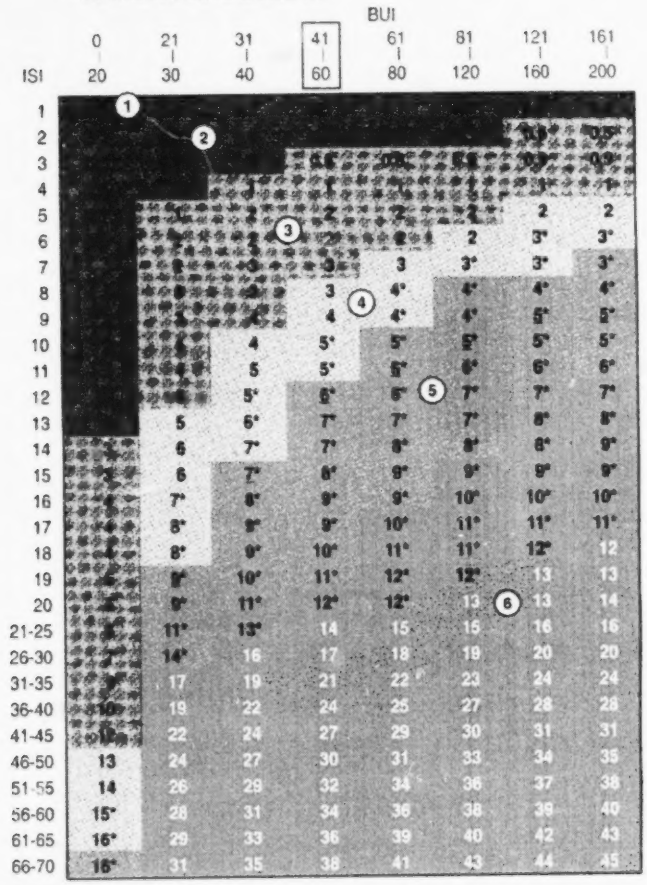
Constants: foliar moisture content = 97%; crown base height = 6m

Type of fire: surface intermittent crown* continuous crown _ CFB 50% BUI$_0$

TABLE 4.16
Equilibrium rate of spread (m/min) and fire intensity class

M-3 dead balsam fir mixedwood - leafless / 30% dead fir

INTENSITY CLASS
1 < 10 kW/m
2 10 – 500
3 500 – 2 000
4 2 000 – 4 000
5 4 000 – 10 000
6 > 10 000



Constants: foliar moisture content = 97%; crown base height = 6m
Type of fire: **surface** **intermittent crown*** continuous crown _ CFB 50% BUI$_0$

TABLE 4.17
Equilibrium rate of spread (m/min)
and fire intensity class

M-3 dead balsam fir mixedwood - leafless / 60% dead fir

INTENSITY CLASS
1 < 10 kW/m
2 10 – 500
3 500 – 2 000
4 2 000 – 4 000
5 4 000 – 10 000
6 > 10 000

	BUI							
	0	21	31	41	61	81	121	161
ISI	20	30	40	60	80	120	160	200
1				0.8	0.9	1	1	1
2		2	2	2	2	3	3*	3*
3		4	4*	4*	4*	5*	5*	5*
4		5	6*	6*	7*	7*	7*	7*
5	4	7*	8*	8*	9*	9*	10*	10*
6	4	9*	10*	11*	11*	12*	12	13
7	5	11*	12*	13*	14	15	15	15
8	7	12*	14*	16	17	17	18	18
9	8	14*	16	18	19	20	21	21
10	9	16	19	20	22	23	24	24
11	10*	18	21	23	24	25	26	27
12	11*	20	23	25	27	28	29	30
13	12*	22	25	28	29	31	32	32
14	13	24	27	30	32	33	35	35
15	14	26	29	32	34	36	37	38
16	15*	28	32	35	37	39	40	41
17	15*	30	34	37	39	41	42	43
18	16*	31	35	39	41	43	45	46
19	17*	33	37	41	44	46	47	48
20	18*	35	39	43	46	48	50	51
21-25	21*	39	45	49	52	55	56	57
26-30	24	46	52	57	61	64	66	67
31-35	27	52	59	64	69	72	74	76
36-40	30	57	64	70	75	78	81	82
41-45	32	60	68	75	80	84	86	88
46-50	33	64	72	79	84	88	91	93
51-55	34	66	75	82	87	92	95	96
56-60	36	68	77	85	90	95	98	99
61-65	36	70	79	87	92	97	100	102
66-70	37	71	81	88	94	99	102	104

Constants: foliar moisture content = 97%; crown base height = 6m
Type of fire: **surface** **intermittent crown*** **continuous crown** CFB 50% BUI$_0$

TABLE 4.18
Equilibrium rate of spread (m/min) and fire intensity class

M-3 dead balsam fir mixedwood - leafless / 100% dead fir

INTENSITY CLASS
1 < 10 kW/m
2 10 - 500
3 500 - 2 000
4 2 000 - 4 000
5 4 000 - 10 000
6 > 10 000

ISI \ BUI	0	21	31	41	61	81	121	161
	20	30	40	60	80	120	160	200
1	(2)	(3)	2	2	2	2	2*	2*
2		5	(4) 5*	6*	6*	6*	6*	6*
3		8*	9*	(5) 10*	10*	10*	11*	11*
4	11*	12*	13*	14	15	15	15	15
5	14*	16	17	18	19	20	20	20
6	17	20	21	23	24	25	25	25
7	21	23	26	27	29	29	30	30
8	24	27	30	32	33	34	35	35
9	27	31	34	36	38	39	40	40
10	30	34	38	40	42	43	44	44
11	33	38	42	44	(6) 46	48	49	49
12	36	41	45	48	50	52	53	53
13	39	44	49	52	54	56	57	57
14	42	48	52	56	58	60	61	61
15	45	51	56	59	62	64	65	65
16	47	54	59	63	66	68	69	69
17	50	56	62	66	69	71	73	73
18	52	59	65	69	72	75	76	76
19	54	62	68	72	75	78	79	79
20	57	64	70	75	78	81	82	82
21-25	63	71	78	83	87	89	91	91
26-30	71	80	88	93	98	101	103	103
31-35	77	87	95	102	107	110	112	112
36-40	82	92	101	108	113	117	119	119
41-45	85	97	106	113	118	122	124	124
46-50	88	100	109	117	122	126	128	128
51-55	90	102	112	119	125	129	131	131
56-60	92	104	114	121	127	131	134	134
61-65	93	105	116	123	129	133	135	135
66-70	94	106	117	124	130	134	137	137

Constants: crown base height = 6m
Type of fire: surface intermittent crown* continuous crown _ CFB 50% BUI_0

TABLE 4.19
Equilibrium rate of spread (m/min) and fire intensity class

M-4 dead balsam fir mixedwood - green / 30% dead fir

INTENSITY CLASS
1 < 10 kW/m
2 10 - 500
3 500 - 2 000
4 2 000 - 4 000
5 4 000 - 10 000
6 > 10 000

ISI \ BUI	0	21	31	41	61	81	121	161
	20	30	40	60	80	120	160	200
1								
2								
3								
4						0.5	0.5	0.5
5					0.8	0.8	0.8	0.9
6					1	1	1	1
7				2	2	2	2	2
8			2	2	2	2	2	2
9		2	2	3	3	3	3	3
10		3	3	3	3	3	4	4
11		3	4	4	4	4	4	4
12		4	4	5	5	5	5	5
13		5	5	6	6	6	6	6
14		5	6	6	7	7	7	7
15	5	6	7	7	7	7	8	8
16	6	7	8	8	8	8	9	9
17	7	8	8	9	9	9	10	10
18	7	8	9	10	10	11	11	11
19	8	9	10	11	11	12	12	12
20	9	10	11	12	12	13	13	13
21-25	11	12	14	14	15	16	16	17
26-30	14	16	18	19	20	20	21	22
31-35	18	20	22	23	24	25	26	27
36-40	20	23	25	27	28	29	30	31
41-45	23	26	29	31	32	33	34	35
46-50	25	29	31	33	35	36	37	38
51-55	27	31	34	36	38	39	40	41
56-60	29	33	36	38	40	41	42	43
61-65	30	34	38	40	42	43	44	45
66-70	31	36	39	42	44	45	46	47

Constants: foliar moisture content = 97%; crown base height = 6m
Type of fire: **surface** **intermittent crown*** **continuous crown** _ CFB 50% BUI$_0$

TABLE 4.20
Equilibrium rate of spread (m/min) and fire intensity class

M-4 dead balsam fir mixedwood - green / 60% dead fir

INTENSITY CLASS
1 < 10 kW/m
2 10 – 500
3 500 – 2 000
4 2 000 – 4 000
5 4 000 – 10 000
6 > 10 000

ISI \ BUI	0	21	31	41	61	81	121	161
	20	30	40	60	80	120	160	200
1								
2	②							
3								
4						2	2	2
5		③			3	3*	3*	3*
6				4	4*	5*	5*	5*
7		5	④	5*	6*	6*	6*	6*
8		6*		6*	7*	7*	7*	7*
9	6	7*		8*	⑤ 8*	9*	9*	9*
10	7*	8*		9*	10*	10*	11*	11*
11	8*	10*		11*	11*	12*	12	13
12	10*	11*		12*	13	14	14	14
13	11*	13*		14	15	15	16	16
14	12*	14*		15	16	17	18	18
15	14*	15		17	18	⑥ 19	20	20
16	15*	17		19	20	21	21	22
17	16	18		20	22	23	23	24
18	18	20		22	23	24	25	26
19	19	21		24	25	26	27	28
20	20	23		25	27	28	29	29
21-25	24	27		30	32	33	34	35
26-30	30	34		37	40	42	43	44
31-35	35	40		44	47	49	51	52
36-40	40	45		50	53	56	57	58
41-45	44	50		55	58	61	63	64
46-50	48	54		59	63	66	68	69
51-55	51	57		63	67	70	72	74
56-60	53	60		66	70	73	76	77
61-65	55	62		68	73	76	78	80
66-70	57	64		70	75	79	81	83

Constants: foliar moisture content = 97%; crown base height = 6m
Type of fire: **surface** **intermittent crown*** **continuous crown** CFB 50% BUI_0

TABLE 4.21
Equilibrium rate of spread (m/min)
and fire intensity class

M-4 dead balsam fir mixedwood - green /100% dead fir

INTENSITY CLASS
1 < 10 kW/m
2 10 - 500
3 500 - 2 000
4 2 000 - 4 000
5 4 000 - 10 000
6 > 10 000

ISI \ BUI	0 - 20	21 - 30	31 - 40	41 - 60	61 - 80	81 - 120	121 - 160	161 - 200
1	(2)							
2					2	3	3*	3*
3		(3)		4	(4) 4*			
4			5*					
5		7			(5)			
6		8*						12
7					13	14	15	15
8				15	16	17	17	18
9		14*	16	17	18	19	20	20
10			18	20	21	22	23	23
11		18	20	22	23	25	25	26
12		20	22	24	26	27	28	29
13		22	24	27	28	30	31	31
14	12	23	26	29	31	32	33	34
15	13	25	28	31	33	(6) 35	36	37
16	14*	27	31	33	36	37	39	39
17	15*	29	32	36	38	40	41	42
18	16*	30	34	38	40	42	44	44
19		32	36	40	42	45	46	47
20		34	38	42	45	47	48	49
21-25		38	43	48	51	53	55	56
26-30		45	51	56	60	63	65	65
31-35	27	51	58	64	68	71	74	75
36-40	29	56	64	70	75	78	81	82
41-45	32	61	68	75	80	84	87	88
46-50	34	64	73	80	85	89	92	94
51-55	35	67	76	83	89	93	96	98
56-60	36	70	79	86	92	96	100	101
61-65	37	72	81	89	95	100	102	104
66-70	38	73	83	91	97	105	105	108

Constants: crown base height = 6m
Type of fire: surface intermittent crown* continuous crown _ CFB 50% BUI$_0$

TABLE 4.22
Equilibrium rate of spread (m/min)
and fire intensity class

S-1 jack or lodgepole pine slash

INTENSITY CLASS
1 < 10 kW/m
2 10 - 500
3 500 - 2 000
4 2 000 - 4 000
5 4 000 - 10 000
6 > 10 000

ISI	BUI 0	21	31	41	61	81	121	161
	20	30	40	60	80	120	160	200
1		0.6	0.7	0.8	0.9	1	1	1
2		2	2	2	2	2	2	2
3	3	3	3	3	4	4	4	4
4	4	4	5	5	5	6	6	6
5	5	5	6	6	7	7	8	8
6	6	6	7	8	8	9	9	10
7	7	7	8	9	10	11	11	11
8	8	9	10	11	12	13	13	13
9	9	10	11	13	14	14	15	15
10	10	11	12	14	15	16	17	17
11	11	12	14	16	17	18	19	19
12	12	13	15	17	19	20	21	21
13	13	14	17	19	20	22	23	23
14	14	15	18	20	22	23	24	25
15	15	16	19	22	24	25	26	27
16	16	18	21	23	25	27	28	29
17	17	19	22	25	27	29	30	30
18	18	20	23	26	28	30	31	32
19	19	21	24	28	30	32	33	34
20	20	22	25	29	31	33	35	36
21-25	21	25	29	33	36	38	40	41
26-30	25	30	34	39	42	45	47	48
31-35	30	34	40	45	48	51	54	55
36-40	34	37	44	50	54	57	60	61
41-45	37	41	48	54	59	62	65	66
46-50	41	44	51	58	62	66	68	71
51-55	44	46	54	61	66	70	73	75
56-60	46	48	57	64	69	73	77	78
61-65	48	50	59	66	72	76	80	81
66-70	50	52	61	68	74	79	82	84

Type of fire: **surface** BUI$_0$

TABLE 4.23
Equilibrium rate of spread (m/min)
and fire intensity class

S-2 white spruce-balsam slash

INTENSITY CLASS

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI 0 – 20	21 – 30	31 – 40	41 – 60	61 – 80	81 – 120	121 – 160	161 – 200
1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2	0.3	0.4	0.5	0.5	0.6	0.6	0.7	0.7
3	0.5	0.8	1	1	1	1	1	1
4	0.8	1	1	2	2	2	2	2
5	0.8	2	2	2	3	3	3	3
6	1	2	3	3	3	4	4	4
7	1	3	3	4	4	5	5	5
8	2	4	4	5	5	5	6	6
9	2	4	5	6	6	6	7	7
10	2	5	6	6	7	7	8	8
11	2	6	7	7	8	8	9	9
12	3	6	7	8	9	10	10	10
13	3	7	8	9	10	11	11	11
14	3	8	9	10	11	12	12	12
15	4	8	10	11	12	13	13	13
16	4	9	10	12	13	14	14	14
17	4	10	11	13	14	15	15	16
18	4	10	12	13	15	16	16	17
19	5	11	13	14	16	16	17	18
20	5	11	13	15	16	17	18	19
21-25	6	13	15	17	19	20	21	21
26-30	7	16	19	21	23	24	25	26
31-35	8	18	21	24	26	28	29	29
36-40	9	20	23	26	29	30	32	32
41-45	9	22	25	29	31	33	34	36
46-50	10	23	27	30	33	35	36	37
51-55	10	24	28	32	34	37	38	39
56-60	11	25	29	33	36	38	39	40
61-65	11	26	30	34	37	39	41	42
66-70	11	26	31	35	38	40	42	42

Type of fire: surface BUI

TABLE 4.24
Equilibrium rate of spread (m/min)
and fire intensity class

S-3 coastal cedar-hemlock-Douglas-fir slash

INTENSITY CLASS

	1	< 10 kW/m
	2	10 – 500
	3	500 – 2 000
	4	2 000 – 4 000
	5	4 000 – 10 000
	6	> 10 000

ISI \ BUI	0 – 20	21 – 30	31 – 40	41 – 60	61 – 80	81 – 120	121 – 160	161 – 200
1								
2			0.1	0.1	0.2	0.2	0.2	0.2
3		0.4	0.5	0.5	0.6	0.8	0.8	0.8
4	0.4	0.9	1	1	1	1	1	1
5	1	2	2	2	2	2	2	3
6	1	2	3	3	4	4	4	4
7	2	4	4	5	5	5	6	6
8	2	5	6	6	7	7	8	8
9	3	6	7	8	9	10	10	10
10	3	8	9	10	11	12	13	13
11	4	10	11	13	14	15	15	16
12	5	11	13	15	16	17	18	18
13	6	13	15	17	19	20	21	21
14	6	15	18	20	21	23	24	24
15	7	17	20	22	24	26	27	27
16	8	19	22	25	27	28	29	30
17	9	20	24	27	29	31	32	33
18	10	22	26	29	32	34	35	36
19	10	24	28	31	34	36	38	39
20	11	25	30	33	36	39	40	41
21-25	13	30	35	39	43	45	47	48
26-30	15	36	42	47	51	54	57	58
31-35	17	40	47	53	58	61	64	65
36-40	19	43	51	57	62	66	69	70
41-45	20	45	53	60	66	69	72	74
46-50	20	47	55	62	67	71	74	76
51-55	21	48	56	63	69	73	76	78
56-60	21	48	57	64	69	74	77	79
61-65	21	49	57	66	70	75	78	79
66-70	21	49	58	66	71	75	78	80

Type of fire surface BUI

TABLE 4.25
Equilibrium rate of spread (m/min) and fire intensity class

O-1a matted grass

INTENSITY CLASS

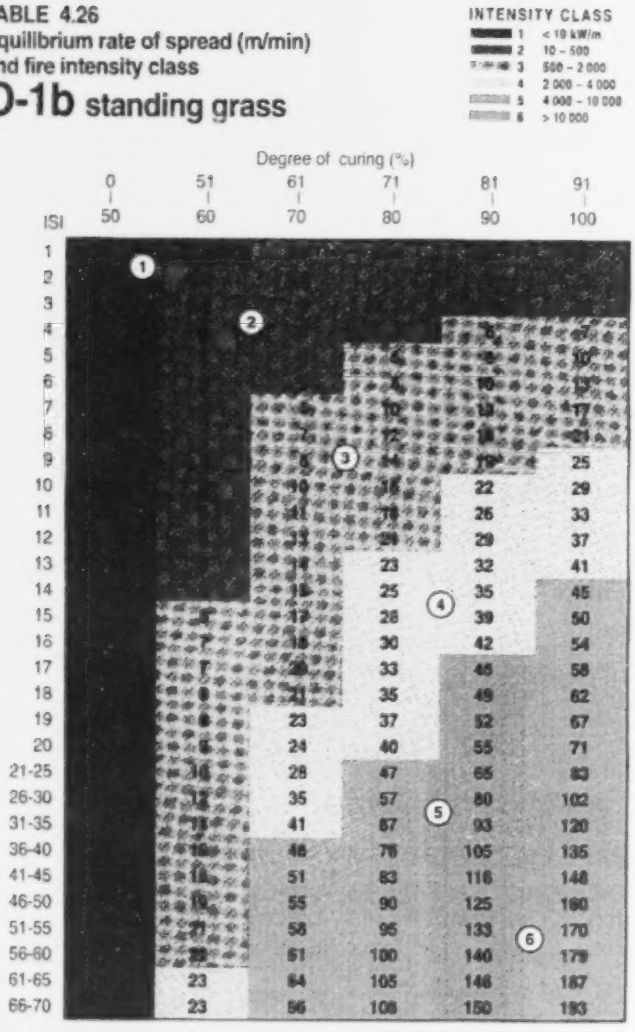
1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

	Degree of curing (%)					
	0	51	61	71	81	91
ISI	50	60	70	80	90	100
1						
2						
3						8
4	①	②			7	9
5				8	9	11
6				9	11	14
7			9	11	14	18
8			7	12	16	21
9			8	13	18	24
10			③	16	21	27
11			10	17	24	30
12			11	19	26	34
13			13	21	29	37
14			14	22	31	40
15			15	24	34	43
16			16	26	④ 36	46
17			18	28	39	50
18			19	30	41	53
19			21	31	43	56
20			22	33	46	59
21-25		20	23	36	53	67
26-30		24	27	45	63	81
31-35		28	32	52	72	93
36-40		31	35	58	81	103
41-45		34	38	63	⑤ 88	113
46-50		37	41	68	94	121
51-55		39	44	72	100	128
56-60		41	46	75	105	⑥ 134
61-65		42	48	78	109	140
66-70		43	49	81	113	144

Constants: surface fuel load = 3t/ha
Type of fire: **surface**

TABLE 4.26
Equilibrium rate of spread (m/min)
and fire intensity class

O-1b standing grass



Constants: surface fuel load = 3t/ha

TABLE 5.1

Spread distance (m)

equilibrium ROS: all fuel types

accelerating ROS: open fuels and surface fires in closed fuel types

equil	Elapsed time											
ROS	15 min		30 min		45 min		1h		2h		3h	
0.2	3	2	6	4	9	7	12	10	24	22	36	34
0.4												
0.6	9	5	18	13	27	22	36	31	72	87	108	103
1	15	8	30	22	45	36	60	51	120	111	180	171
2												
3	45	24	90	65	135	109	180	154	360	334	540	514
4												
5	75	39	150	108	225	182	300	257	600	557	900	857
6												
7	105	55	210	151	315	254	420	359	840	779	1260	1199
8												
9	135	71	270	194	405	327	540	462	1080	1002	1620	1542
10												
12	180	94	360	259	540	436	720	616	1440	1336	2160	2056
14												
16	240	126	480	345	720	582	960	821	1920	1781	2880	2741
18												
20	300	157	600	432	900	727	1200	1026	2400	2226	3600	3426
25												
30	450	236	900	647	1350	1091	1800	1539	3600	3339	5400	5139
35												
40	600	314	1200	863	1800	1454	2400	2053	4800	4452	7200	6852
45												
50	750	393	1500	1079	2250	1818	3000	2568	6000	5565	9000	8565
55												
60	900	471	1800	1295	2700	2181	3600	3079	7200	6678	10800	10278
65												
70	1050	550	2100	1511	3150	2545	4200	3592	8400	7791	12600	11991
75												
80	1200	628	2400	1726	3600	2908	4800	4105	9600	8904	14400	13704
85												
90	1350	707	2700	1942	4050	3272	5400	4618	10800	10017	16200	15417
95												
100	1500	785	3000	2168	4500	3635	6000	5131	12000	11130	18000	17130

Red figures are distances for equilibrium ROS in all fuel types

Black figures are distances for accelerating ROS in open fuel types and surface fires in closed fuel types. Open fuel types are C-1, D-1, O-1, S-1, S-2, S-3 (C-2, C-7). C-2 and C-7 are considered open types when the crown closure is less than 50%.

TABLE 5.2

Spread distance (m)

accelerating ROS: crown fires in closed fuel types

equil. ROS	Elapsed time											
	15 min		30 min		45 min		1 h		2 h		3 h	
0.2	1	1	3	4	6	7	8	10	21	22	32	34
0.4	2	2	5	6	9	11	13	15	31	33	48	51
0.6	3	4	9	12	17	21	25	30	61	66	97	102
0.8	4	5	12	17	23	28	34	40	82	88	129	136
1	5	7	15	21	28	35	42	50	102	110	162	170
2	9	13	30	41	56	69	84	101	204	220	324	341
3	14	22	46	62	84	106	127	151	305	331	485	511
4	19	29	61	83	113	140	169	202	407	441	646	681
5	24	37	76	104	141	177	211	252	508	552	808	852
6	28	44	91	125	169	212	254	303	610	662	969	1022
7	33	52	106	146	197	248	296	353	711	773	1131	1193
8	38	59	121	167	225	283	338	403	812	883	1292	1363
9	43	67	137	187	253	319	380	454	914	994	1454	1534
10	47	74	152	208	281	354	423	504	1015	1104	1615	1704
12	57	89	182	250	338	426	507	605	1219	1325	1938	2045
14	66	104	213	291	394	496	592	706	1422	1546	2261	2386
16	78	119	243	333	450	568	676	807	1625	1766	2584	2726
18	85	133	273	375	507	639	761	907	1829	1987	2907	3067
20	95	148	303	417	563	710	845	1008	2031	2208	3231	3408
25	118	185	379	521	704	887	1056	1259	2538	2758	4037	4257
30	142	222	455	625	884	1065	1267	1513	3047	3312	4846	5112
35	165	259	531	729	985	1242	1478	1764	3554	3862	5652	5963
40	189	297	607	833	1126	1420	1690	2017	4062	4416	6461	6816
45	213	334	683	937	1267	1597	1901	2268	4569	4966	7267	7667
50	236	371	758	1041	1407	1775	2112	2521	5078	5520	8076	8520
55	260	408	834	1145	1548	1952	2323	2772	5585	6070	8882	9371
60	284	445	910	1250	1689	2130	2535	3025	6093	6624	9692	10224
65	307	482	986	1354	1830	2307	2746	3276	6600	7174	10497	11076
70	331	519	1062	1458	1970	2484	2957	3530	7109	7728	11307	11928
75	354	556	1138	1562	2111	2662	3168	3781	7616	8278	12112	12780
80	378	593	1213	1668	2251	2839	3380	4034	8124	8832	12922	13632
85	402	630	1289	1771	2392	3016	3591	4285	8631	9382	13727	14485
90	426	667	1365	1874	2533	3194	3802	4538	9140	9936	14537	15336
95	449	704	1441	1979	2673	3371	4013	4789	9647	10486	15342	16189
100	473	741	1517	2083	2814	3549	4224	5042	10155	11040	16153	17040

Black figures are distances for intermittent crown fires with accelerating ROS (50% CFB)
Red figures are distances for continuous crown fires with accelerating ROS (80% CFB)

TABLE 3.1

Spread distance (m)

equilibrium ROS: all fuel types
accelerating ROS: open fuels and surface fires in closed fuel types

TABLE 5.2

Spread distance (m)

accelerating ROS;
crown fires in closed fuel types

TABLE 6.1

Fire Area (ha) Perimeter (m) timber and slash fuel types

Spread Dist.	Effective wind speed (km/h)										
	0	5	10	15	20	25	30	35	40	45	50
50	0.2	0.2	0.1	0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	157	148	133	121	114	110	108	106	105	104	103
150	2	2	1	1	1	1	0.5	0.4	0.4	0.3	0.3
	471	445	399	364	343	330	323	317	314	312	310
250	5	4	3	2	2	2	1	1	1	1	1
	785	742	665	607	572	551	538	529	523	519	516
400	13	11	9	6	5	4	3	3	2	2	2
	1257	1188	1064	971	915	881	860	847	837	831	826
600	28	25	19	14	11	9	7	6	6	5	5
	1885	1782	1596	1457	1372	1322	1290	1270	1256	1246	1239
1000	79	70	53	40	31	25	20	18	16	14	13
	3142	2970	2660	2428	2287	2203	2151	2116	2093	2077	2065
1500	177	157	120	89	69	55	46	40	35	32	29
	4712	4455	3989	3642	3431	3305	3226	3175	3140	3115	3097
2500	491	436	333	248	191	153	128	110	98	88	81
	7854	7425	6649	6071	5718	5508	5376	5291	5233	5192	5162
4000	1257	1117	852	635	489	393	328	282	250	226	207
	12566	11880	10638	9713	9149	8812	8602	8466	8373	8307	8260
L/B:	1.0	1.1	1.5	2.0	2.6	3.3	3.8	4.4	5.0	5.6	6.1

Red figures are area

Black figures are perimeter length

TABLE 6.2

Fire Area (ha)
Perimeter (m) grass fuel types

Spread Dist.	Effective wind speed (km/h) 0	5	10	15	20	25	30	35	40	45	50
50	0.2	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	157	117	110	107	106	105	104	104	103	103	103
150	2	1	1	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3
	471	350	330	322	318	315	313	311	310	309	308
250	5	2	2	1	1	1	1	1	1	1	1
	785	584	551	537	530	525	521	518	516	514	513
400	13	5	4	3	3	3	2	2	2	2	2
	1257	935	881	859	847	839	833	829	826	823	821
600	26	12	9	7	6	6	5	5	5	4	4
	1885	1402	1322	1289	1271	1259	1250	1244	1239	1234	1231
1000	79	34	25	20	18	16	15	14	13	12	12
	3142	2336	2203	2149	2118	2098	2084	2073	2064	2057	2052
1500	177	76	55	46	40	36	33	31	29	27	26
	4712	3505	3304	3223	3177	3147	3126	3109	3096	3086	3077
2500	491	211	153	127	111	100	92	86	81	76	73
	7854	5841	5507	5372	5295	5245	5209	5182	5161	5143	5129
4000	1257	541	392	325	285	257	236	219	206	195	186
	12566	9346	8812	8595	8472	8392	8335	8291	8257	8229	8206
L/B:	1.0	2.3	3.2	3.5	4.4	4.9	5.3	5.7	6.1	6.4	6.8

Red figures are area

Black figures are perimeter length

TABLE 6.1

Fire Area(ha) Perimeter(m) timber and slash fuel types

100											
200											
300											
500											
800											
1200											
2000											
3000											
5000											

TABLE E2

Fire Area (ha)
Perimeter (m) grass fuel types

TABLE 7.1
Perimeter growth rate (m/min)

PGR timber and slash fuel types

equil.	Effective wind speed (km/h)										
ROS	0	5	10	15	20	25	30	35	40	45	50
0.2	1	1	1	<1	<1	<1	<1	<1	<1	<1	<1
0.4	1	1	1	1	1	1	1	1	1	1	1
0.6	2	2	2	1	1	1	1	1	1	1	1
0.8	3	2	2	2	2	2	2	2	2	2	2
1	3	3	3	2	2	2	2	2	2	2	2
2	6	6	5	5	5	4	4	4	4	4	4
3	9	9	8	7	7	7	6	6	6	6	6
4	13	12	11	10	9	9	9	8	8	8	8
5	16	15	13	12	11	11	11	11	10	10	10
6	19	18	16	15	14	13	13	13	13	12	12
7	22	21	19	17	16	15	15	15	15	15	14
8	25	24	21	19	18	18	17	17	17	17	17
9	28	27	24	22	21	20	19	19	19	19	19
10	31	30	27	24	23	22	22	21	21	21	21
12	38	36	32	29	27	26	26	25	25	25	25
13	41	39	35	32	30	29	28	28	27	27	27
14	44	42	37	34	32	31	30	30	29	29	29
15	47	45	40	36	34	33	32	32	31	31	31
16	50	48	43	39	37	35	34	34	33	33	33
17	53	50	45	41	39	37	37	36	36	35	35
18	57	53	48	44	41	40	39	38	38	37	37
20	63	59	53	49	46	44	43	42	42	42	41
25	79	74	66	61	57	55	54	53	52	52	52
30	94	89	80	73	69	66	65	63	63	62	62
35	110	104	93	85	80	77	75	74	73	73	72
40	126	119	106	97	91	88	86	85	84	83	83
45	141	134	120	109	103	99	97	95	94	93	43
50	157	148	133	121	114	110	108	106	105	104	103
55	173	163	146	134	126	121	118	116	115	114	114
60	188	178	160	146	137	132	129	127	126	125	124
65	204	193	173	158	149	143	140	138	136	135	134
70	220	208	186	170	160	154	151	148	147	145	145
75	236	223	199	182	172	165	161	159	157	156	155
80	251	238	213	194	183	176	172	169	167	166	165
85	267	252	239	219	206	198	194	190	188	187	186
90	283	267	239	219	206	198	194	190	188	187	186
95	298	282	253	231	217	209	204	201	199	197	196
100	314	297	266	243	229	220	215	212	209	208	206

TABLE 7.2
Perimeter growth rate (m/min)

PGR grass fuel types

equil.	Effective wind speed (km/h)										
ROS	0	5	10	15	20	25	30	35	40	45	50
0.2	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
0.4	1	1	1	1	1	1	1	1	1	1	1
0.6	2	1	1	1	1	1	1	1	1	1	1
0.8	3	2	2	2	2	2	2	2	2	2	2
1	3	2	2	2	2	2	2	2	2	2	2
2	6	5	4	4	4	4	4	4	4	4	4
3	9	7	7	6	6	6	6	6	6	6	6
4	13	9	9	9	8	8	8	8	8	8	8
5	16	12	11	11	11	10	10	10	10	10	10
6	19	14	13	13	13	13	13	12	12	12	12
7	22	16	15	15	15	15	15	15	14	14	14
8	25	19	18	17	17	17	17	17	17	16	16
9	28	21	20	19	19	19	19	19	19	19	18
10	31	23	22	21	21	21	21	21	21	21	21
12	38	28	26	26	25	25	25	25	25	25	25
13	41	30	29	28	28	27	27	27	27	27	27
14	44	33	31	30	30	29	29	29	29	29	29
15	47	35	33	32	32	31	31	31	31	31	31
16	50	37	35	34	34	34	33	33	33	33	33
17	53	40	37	37	36	36	35	35	35	35	35
18	57	42	40	39	38	38	38	37	37	37	37
20	63	47	44	43	42	42	42	41	41	41	41
25	79	58	55	54	53	52	52	52	52	51	51
30	94	70	66	64	64	63	63	62	62	62	62
35	110	82	77	75	74	73	73	73	72	72	72
40	126	93	88	86	85	84	83	83	83	82	82
45	141	105	99	97	96	94	94	93	93	93	92
50	157	117	110	107	106	105	104	104	103	103	103
55	173	129	121	118	116	115	115	114	114	113	113
60	188	140	132	129	127	126	125	124	124	123	123
65	204	152	143	140	138	136	135	135	134	134	133
70	220	164	154	150	148	147	146	145	145	144	144
75	236	175	165	161	159	157	156	155	155	154	154
80	251	187	176	172	169	168	167	166	165	165	164
85	267	199	187	183	180	178	177	176	175	175	174
90	283	210	198	193	191	189	188	187	186	185	185
95	298	222	209	204	201	199	198	197	196	195	195
100	314	234	220	215	212	210	208	207	206	206	205

TABLE 7.1
Perimeter growth rate (m/min)

PGR timber and slash fuel types

FDI	Effective wind speed (km/h)										
	0	5	10	15	20	25	30	35	40	45	50
0.2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
0.4	1	1	1	1	1	1	1	1	1	1	1
0.6	2	2	2	1	1	1	1	1	1	1	1
0.8	3	2	2	2	2	2	2	2	2	2	2
1	3	3	3	2	2	2	2	2	2	2	2
2	6	6	5	5	5	4	4	4	4	4	4
3	9	9	8	7	7	7	6	6	6	6	6
4	13	12	11	10	9	9	9	8	8	8	8
5	16	15	13	12	11	11	11	11	10	10	10
6	19	18	16	15	14	13	13	13	13	12	12
7	23	21	19	17	16	15	15	15	15	15	14
8	25	24	21	19	18	18	17	17	17	17	17
9	28	27	24	22	21	20	19	19	19	19	19
10	31	30	27	24	23	22	22	21	21	21	21
12	38	36	32	29	27	26	26	25	25	25	25
13	41	39	35	32	30	29	28	28	27	27	27
14	44	42	37	34	32	31	30	30	29	29	29
15	47	45	40	36	34	33	32	32	31	31	31
16	50	48	43	39	37	35	34	34	33	33	33
17	53	50	45	41	39	37	37	36	36	35	35
18	57	53	48	44	41	40	39	38	38	37	37
20	63	59	53	49	46	44	43	42	42	42	41
25	79	74	66	61	57	55	54	53	52	52	52
30	94	89	80	73	69	66	65	63	63	62	62
35	110	104	93	85	80	77	75	74	73	73	72
40	126	119	106	97	91	88	86	85	84	83	83
45	141	134	120	109	103	99	97	95	94	93	93
50	157	148	133	121	114	110	108	106	105	104	103
55	173	163	146	134	126	121	118	116	115	114	114
60	188	178	160	146	137	132	129	127	126	125	124
65	204	193	173	158	149	143	140	138	136	135	134
70	220	208	186	170	160	154	151	148	147	145	145
75	236	223	199	182	172	165	161	159	157	156	155
80	251	238	213	194	183	176	172	169	167	166	165
85	267	252	226	219	206	198	194	190	188	187	186
90	283	267	239	219	206	198	194	190	188	187	186
95	298	282	253	231	217	209	204	201	199	197	196
100	314	297	266	243	229	220	215	212	209	208	206

TABLE 7.2
Perimeter growth rate (m/min)

PGR grass fuel types

Curing	Effective wind speed (km/h)										
ROS	0	5	10	15	20	25	30	35	40	45	50
0.2	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
0.4	1	1	1	1	1	1	1	1	1	1	1
0.6	2	1	1	1	1	1	1	1	1	1	1
0.8	3	2	2	2	2	2	2	2	2	2	2
1	3	2	2	2	2	2	2	2	2	2	2
2	6	5	4	4	4	4	4	4	4	4	4
3	9	7	7	6	6	6	6	6	6	6	6
4	13	9	9	9	8	8	8	8	8	8	8
5	16	12	11	11	11	10	10	10	10	10	10
6	19	14	13	13	13	13	13	12	12	12	12
7	22	16	15	15	15	15	15	15	14	14	14
8	25	19	18	17	17	17	17	17	17	16	16
9	29	21	20	19	19	19	19	19	19	19	18
10	31	23	22	21	21	21	21	21	21	21	21
12	38	28	26	26	25	25	25	25	25	25	25
13	41	30	29	28	28	27	27	27	27	27	27
14	44	33	31	30	30	29	29	29	29	29	29
15	47	35	33	32	32	31	31	31	31	31	31
16	50	37	35	34	34	34	33	33	33	33	33
17	53	40	37	37	36	36	35	35	35	35	35
18	57	42	40	39	38	38	38	37	37	37	37
20	63	47	44	43	42	42	42	41	41	41	41
25	79	58	55	54	53	52	52	52	52	51	51
30	94	70	66	64	64	63	63	62	62	62	62
35	110	82	77	75	74	73	73	73	72	72	72
40	126	93	88	86	85	84	83	83	83	82	82
45	141	105	99	97	95	94	94	93	93	93	92
50	157	117	110	107	106	105	104	104	103	103	103
55	173	129	121	118	116	115	115	114	114	113	113
60	188	140	132	129	127	126	125	124	124	123	123
65	204	152	143	140	138	136	135	135	134	134	133
70	220	164	154	150	148	147	146	145	145	144	144
75	236	175	165	161	159	157	156	155	155	154	154
80	251	187	176	172	169	168	167	166	165	165	164
85	267	199	187	183	180	178	177	176	175	175	174
90	283	210	198	193	191	189	188	187	186	185	185
95	298	222	209	204	201	199	198	197	196	195	195
100	314	234	220	215	212	210	208	207	206	206	205

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Appendix 1 Symbols

BISI	Back fire Initial Spread Index
BUI	Buildup Index
BROS	Back fire rate of spread (m/min)
CFB	Crown fraction burned
CBH	Crown base height
FFMC	Fine Fuel Moisture Code
ISI	Initial Spread Index
L/B	Length/breadth ratio
PC	Percent conifer
PDF	Percent dead fir
PH	Percent hardwood
PGR	Perimeter growth rate (m/min)
ROS	Head fire rate of spread (m/min)

Appendix 2 Glossary

Buildup Index - A numerical rating of the total amount of fuel available for combustion that combines DMC and DC. In the FBP System, a buildup effect is applied to the primary ISI-based spread equations to represent the effect of increasing fuel consumption on rate of spread. BUI_0 is theBUI value where this effect is zero and rate of spread depends wholly on the Initial Spread Index.

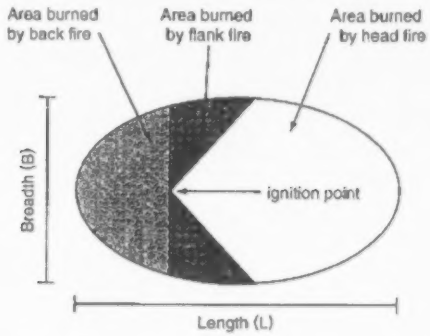
Crown fraction burned - The crown fraction burned is the proportion of tree crowns involved in the fire in a given area. The following descriptive classes are recognized in the FBP System:

Crown fraction burned	Type of fire
< 10%	surface fire
10-89%	intermittent crown fire
> 90%	continuous crown fire

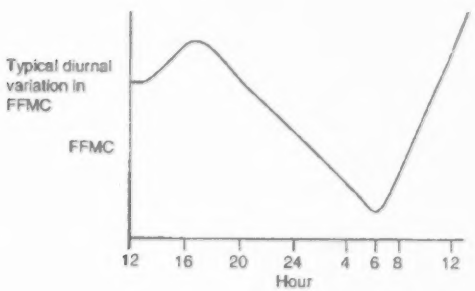
Crown base height - The height, above ground, where the live crown of coniferous trees begins. This value is held constant in each FBP System fuel cept C-6.

ive wind speed - The sum of the vectors of the observed wind speed slope equivalent wind speed.

Elliptical fire growth model - Theory: a free-burning point source fire is an ellipse when fuels are uniform and continuous, topography is homogeneous, windspeed is constant and unidirectional, and the fire is unaffected by supression activities. The length of the ellipse is the sum of the head fire spread distance and the back fire spread distance. Fire shape or length/breadth ratio (L/B) is determined by the wind speed. Fire area and perimeter length are calculated from the total spread distance and the L/B ratio.



Fine Fuel Moisture Code - A numerical rating of the moisture content of litter and other cured fine fuels. This code indicates the relative ease of ignition and flammability of fine fuel. Fine fuel moisture content varies over a daily or diurnal cycle. The daily standard FFMC is calculated from noon weather observations, but represents fine fuel moisture at 1600 LST, when the fine fuel moisture content is at or near the daily minimum. The diurnal FFMC is an estimate of the FFMC at a particular hour, based on the typical daily variation in temperture and relative humidity in the absence of rain. The hourly FFMC is calculated from actual hourly weather observations.



Fire intensity - The rate of heat energy release per unit time per unit length of fire front. Frontal fire intensity is a major determinant of certain fire effects and difficulty of control. Numerically, it is equal to the product of the net heat of combustion, the quantity of fuel consumed in the flaming front and the linear rate of spread.

Fire perimeter - The entire outer edge or boundary of a fire. See elliptical fire growth model.

Foliar moisture content - The percent moisture content by weight of live conifer needles that are at least one year old.

Initial Spread Index - A numerical rating of the expected rate of fire spread. It combines the effects of wind, slope and FFMC on rate of spread but excludes the influence of the variable quantities of fuel.

Rate of spread - The speed at which a fire extends its horizontal dimensions, expressed in terms of distance per unit of time. Generally thought of in terms of a fire's forward movement, or **head fire rate of spread**, but also applicable to **back fire** and **flank fire ROS**.

Slope equivalent wind speed - An approach used in the FBP System whereby the effect of slope on fire spread with zero wind is given a value in units of wind speed.

Type of fire - See crown fraction burned.

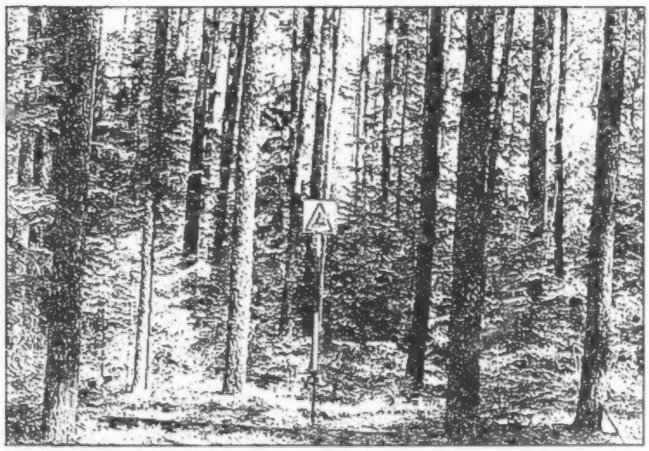
Appendix 3 Examples of FBP System fuel types[1]

The Canadian Forest Fire Behavior Prediction (FBP) System models rate of spread, fuel consumption, fire intensity, and fire growth for 16 national benchmark fuel types. A detailed description of the FBP System fuel types (stand structure, surface and ladder fuels) can be found in Information Report ST-X-3, Development and Structure of the Canadian Forest Fire Behavior Prediction System (Forestry Canada Fire Danger Group 1992). The following photos show the benchmark or most representative example of the stands used to develop the FBP System. The pole in the photos is 180 cm tall. Additional photographs showing typical variations in stand structure and composition (indicating the f condition to which each fuel type is applicable) are found in the poster Groot (1993).

1 from De Groot (1993).

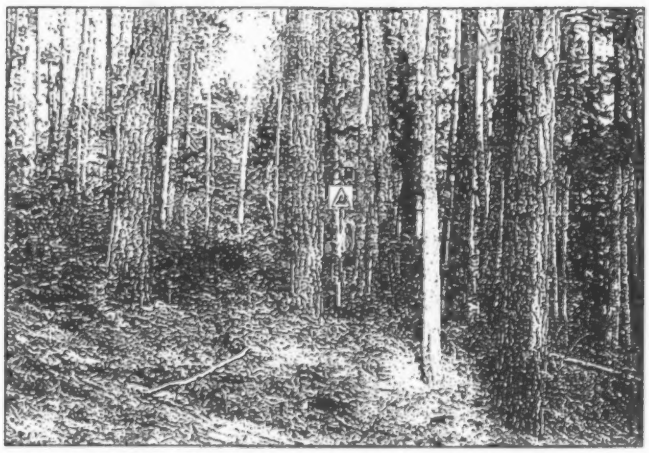
C-1 Spruce-Lichen Woodland Open black spruce stands with lichen understory.

C-2 Boreal Spruce Upland and lowland black spruce, white and Engelmann spruce stands. Does not include spruce-sphagnum bogs. Photo shows upland black spruce.

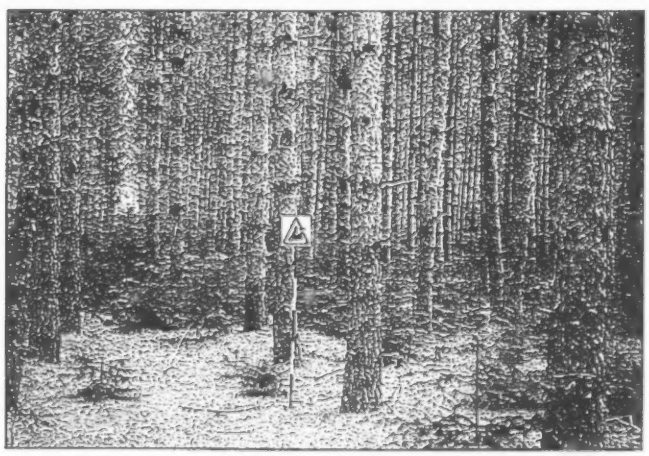


C-3 Mature Jack or Lodgepole Pine Fully stocked mature jack and lodgepole pine stands. Photo is of a jackpine stand.

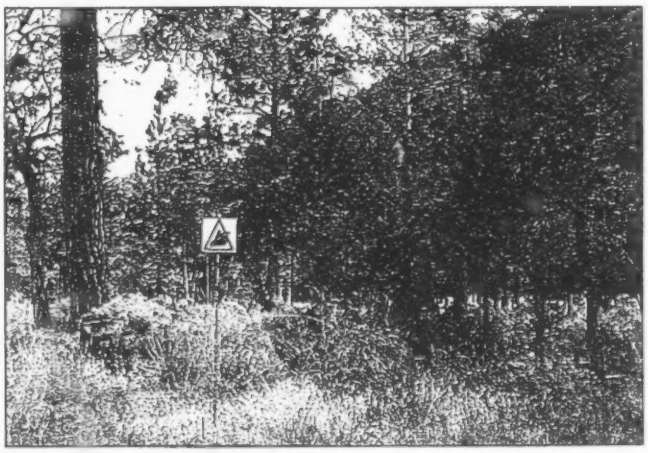
ımature Jack or Lodgepole Pine Stands Densely stocked immature ...d lodgepole pine stands. Photo is of a jackpine stand.



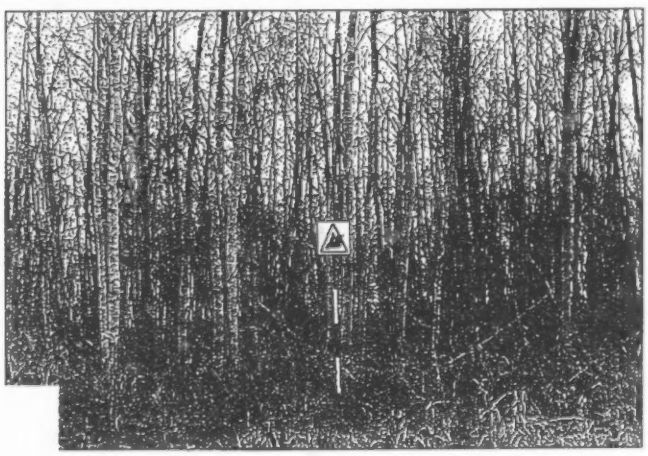
C-5 Red and White Pine Mature red and white pine.



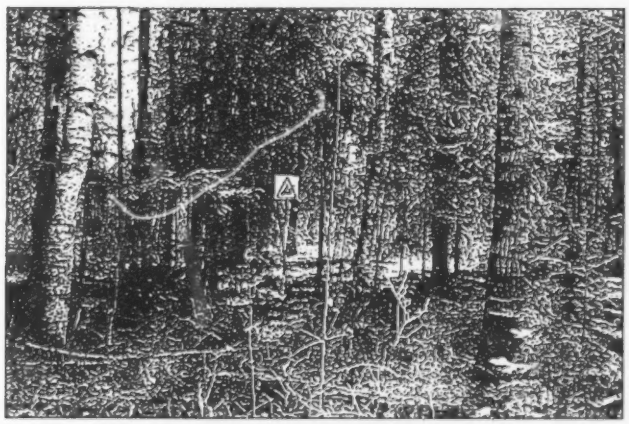
C-6 Conifer Plantation This fuel type is applicable to all conifer plantations with closed crown canopy and no understory shrub layer. Photo is of a red pine plantation.



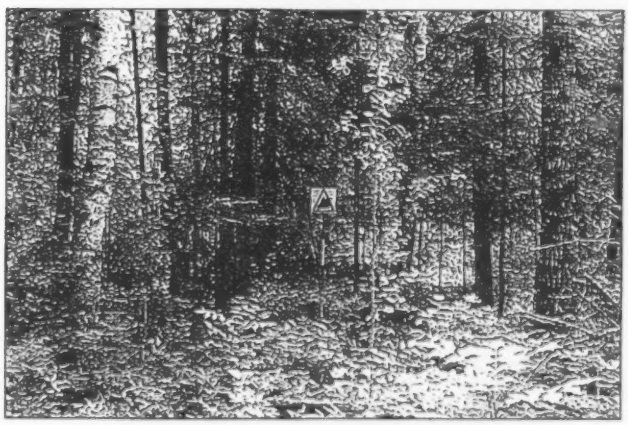
C-7 Ponderosa Pine / Douglas-fir Mixed stands of uneven-aged ponderosa pine and Douglas-fir.



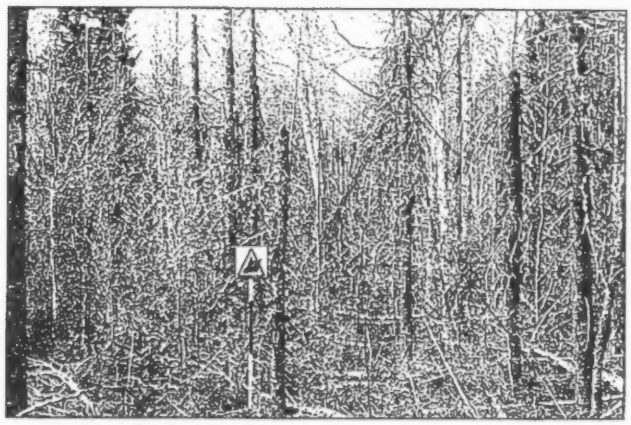
afless Aspen Pure semi-mature trembling aspen stands in the leafless stage.



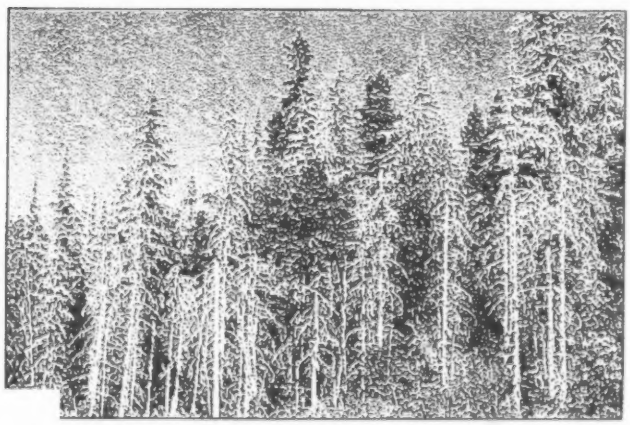
M-1 Boreal Mixedwood - Leafless Mixed stands of boreal species in the leafless stage. Photo shows a stand with 75% coniferous and 25% deciduous component.



M-2 Boreal Mixedwood - Green Mixed stands of boreal species in the green stage. Photo shows a stand with 75% coniferous and 25% deciduous component.

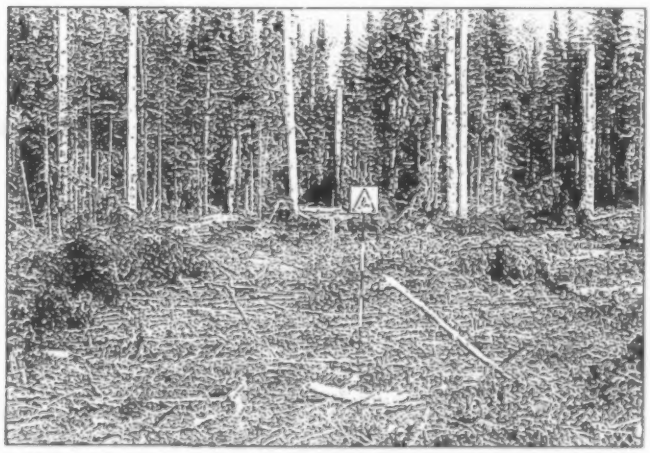


M-3 Dead Balsam Fir/Mixedwood -Leafless Mixed stands of dead balsam fir and boreal mixed wood species in the leafless stage. The stand in the above photo has 60% dead balsam fir and 40% live mixedwood species.



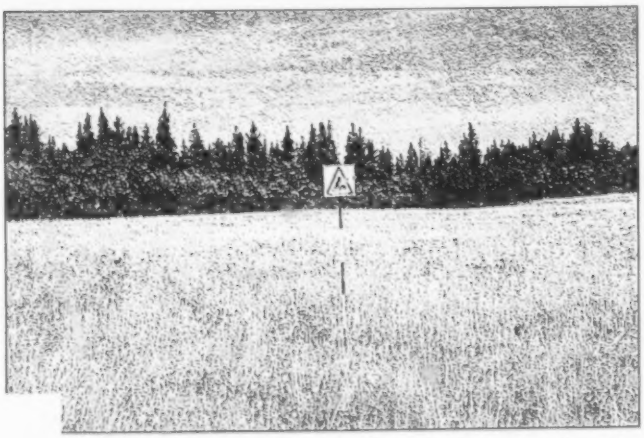
ead Balsam Fir/Mixedwood - Green Mixed stands of dead balsam fir eal mixed wood species in the green stage. The stand in the above photo % dead balsam fir and 40% live mixedwood species.

S-1 Jack or Lodgepole Pine Slash Jack or lodgepole pine slash, 1-2 seasons old.



S-2 White Spruce/Balsam Slash White or Engelmann spruce and balsam or subalpine fir slash, 1-2 seasons old.

S-3 Coastal Cedar/Hemlock/Douglas-fir Slash Western red cedar, western hemlock, and Douglas-fir slash, 1 season old. This fuel type is also applicable to interior wet belt cedar-hemlock slash.



rass Matted and standing grass. The above photo shows well-cured
g grass with a 3 t/ha fuel load.

Appendix 4 Beaufort scale of winds[1]

Wind Speed (km/h)			
Range	Mean	Description	Observed Wind Effects
<2	0	Calm	Smoke rises vertically
2-5	3	Light Air	Direction of drift shown by smoke drift but not by wind vanes
6-11	9	Light Breeze	Wind felt on face, leaves rustle; vanes moved by wind
12-19	16	Gentle Breeze	Leaves and twigs in constant motion; wind extends light flag
20-29	24	Moderate Breeze	Raises dust and loose paper, small branches are moved
30-39	34	Fresh Breeze	Small trees in leaf begin to sway; crested wavelets on inland waters
40-50	44	Strong Breeze	Large branches in motion, whistling in telephone wires, umbrellas used with difficulty
51-61	55	Near Gale	Whole trees in motion; inconvenience felt when walking against wind
62-74	68	Moderate Gale	Breaks twigs off trees, generally impedes progress
75-87	82	Strong Gale	Slight structural damage occurs
88-101	96	Whole Gale	Seldom experienced inland, trees uprooted; considerable structural damage
102-116	110	Storm	Very rarely experienced; widespread damage
116+	125	Hurricane	

[1] Adapted from List (1951).

Appendix 5 FFMC adjustments[1]

Tables A.1 and A.2 can be used to estimate the FFMC for each hour from noon of the current day to noon of the subsequent day for latitudes 48–60° N, in the absence of rain. Table A.3 can be used for topographic adjustments.

Table A.1 Diurnal FFMC Adjustments: 1200-0559 LST

Local Standard Time				Std. FFMC	Local Standard Time													
1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0559
41	43	46	49	50	51	52	53	53	52	51	50	49	48	47	46	45	44	43
45	52	55	57	60	61	62	62	62	61	60	59	58	56	55	54	52	51	50	49
57	61	65	68	70	70	71	70	69	68	66	65	63	62	60	59	58	56	55
59	63	67	70	72	72	72	72	71	69	68	66	65	63	62	61	59	58	57
62	66	70	72	74	74	74	73	72	71	69	68	66	65	63	62	61	59	58
63	67	71	73	75	75	75	74	73	72	70	69	67	66	64	63	61	60	59
64	68	72	74	76	76	76	75	74	72	71	69	68	66	65	64	62	61	60
66	69	73	75	77	77	77	76	75	73	72	70	69	67	66	64	63	62	60
67	71	75	76	78	78	78	77	76	74	72	71	69	68	67	65	64	63	61
69	72	76	78	79	79	79	77	76	75	73	72	70	69	67	66	65	63	62
71	74	77	79	80	80	79	78	77	76	74	73	71	70	68	67	66	64	63
74	76	79	80	81	81	80	79	78	77	75	73	72	71	69	68	66	65	64
76	78	80	81	82	82	81	80	79	77	76	74	73	71	70	68	67	66	65
78	80	81	82	83	83	82	81	80	78	77	75	74	72	71	70	68	67	66
80	81	82	83	84	84	83	82	81	79	78	76	75	73	72	70	69	68	67
82	82	83	84	85	85	84	83	82	80	79	77	76	74	73	71	70	69	68
83	84	85	85	86	86	85	84	83	81	79	78	77	75	74	72	71	70	69
84	85	86	86	87	87	86	85	83	82	80	79	78	76	75	73	72	71	70
85	86	87	87	88	88	87	86	84	83	81	80	79	77	76	74	73	72	71
86	87	88	88	89	89	88	87	85	84	82	81	80	78	77	75	74	73	72
88	88	89	90	90	90	89	88	86	85	83	82	81	79	78	77	75	74	73
89	89	90	91	91	91	90	89	87	86	84	83	82	80	79	78	76	75	74
90	90	91	92	92	92	91	90	88	87	85	84	83	81	80	79	77	76	75
91	91	92	93	93	93	92	91	89	88	86	85	84	82	81	80	78	77	76
92	93	93	94	94	94	93	92	90	89	88	86	85	84	82	81	80	79	77
93	94	94	95	95	95	94	93	91	90	89	87	86	85	83	82	81	80	79
94	95	95	96	96	96	95	94	92	91	90	88	87	86	85	84	82	81	80
95	96	96	97	97	97	96	95	93	92	91	90	88	87	86	85	84	82	81
96	97	97	98	98	98	97	96	94	93	92	91	89	88	87	86	85	84	83
97	98	98	99	99	99	98	97	95	94	93	92	91	90	88	87	86	85	84
98	99	99	100	100	100	99	98	96	95	94	93	92	91	90	89	88	86	85
1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0659
Local Daylight Time					Local Daylight Time													

To estimate the FFMC during the afternoon or overnight, find the daily standard FFMC then move horizontally to the column that corresponds to the prediction time.

[1] Adapted from Lawson et al. (1996)

Appendix 5 FFMC adjustments[1]

Tables A.1 and A.2 can be used to estimate the FFMC for each hour from noon of the current day to noon of the subsequent day for latitudes 48–60° N, in the absence of rain. Table A.3 can be used for topographic adjustments.

Table A.1 Diurnal FFMC Adjustments: 1200-0559 LST

Local Standard Time				Std. FFMC	Local Standard Time													
1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0559
41	43	46	48	50	51	52	53	53	52	51	50	49	48	47	46	45	44	43
55	52	55	57	60	61	62	62	62	61	59	58	56	55	54	52	51	50	49
67	61	65	68	70	70	71	70	68	66	65	63	62	60	58	58	56	55	
70	63	67	70	72	72	72	72	71	69	68	66	65	63	62	61	59	58	57
62	66	70	72	74	74	74	73	72	71	69	68	66	65	63	62	61	59	58
63	67	71	73	75	75	75	74	73	72	70	69	67	66	64	63	61	60	59
64	68	72	74	76	76	76	75	74	72	71	69	68	66	65	64	62	61	60
66	69	73	75	77	77	77	76	75	73	72	70	69	67	66	64	63	62	60
67	71	75	76	78	78	78	77	76	74	72	71	69	68	67	65	64	63	61
69	72	76	78	79	79	79	77	76	75	73	72	70	69	67	66	65	63	62
71	74	77	79	80	80	79	78	77	76	74	73	71	70	68	67	66	64	63
74	75	79	80	81	81	80	79	78	77	75	73	72	71	69	68	66	65	64
76	78	80	81	82	82	81	80	79	77	76	74	73	71	70	69	67	66	65
78	80	81	82	83	83	82	81	80	78	77	75	74	72	71	70	68	67	66
80	81	82	83	84	84	83	82	81	79	78	76	75	73	72	70	69	68	67
82	82	83	84	85	85	84	83	82	80	79	77	76	74	73	71	70	69	68
83	84	85	85	86	86	85	84	83	81	79	78	77	75	74	72	71	70	68
84	85	86	86	87	87	86	85	83	82	80	79	78	76	75	73	72	71	70
85	86	87	87	88	88	87	86	84	83	81	80	79	77	76	74	73	72	71
86	87	88	89	89	89	88	87	85	84	82	81	80	78	77	75	74	73	72
88	88	89	90	90	90	89	88	86	85	83	82	81	79	78	77	75	74	73
89	89	90	91	91	91	90	89	87	86	84	83	82	80	79	78	76	75	74
90	90	91	92	92	92	91	90	88	87	85	84	83	81	80	79	77	76	75
91	91	92	93	93	93	92	91	89	88	86	85	84	82	81	80	79	77	76
92	93	93	94	94	94	93	92	90	89	88	86	85	84	82	81	80	79	77
93	94	94	95	95	95	94	93	91	90	89	87	86	85	83	82	81	80	79
94	95	95	95	96	96	95	94	92	91	90	88	87	86	85	84	82	81	80
95	96	96	97	97	97	96	95	93	92	91	90	88	87	86	85	84	83	81
96	97	97	98	98	98	97	96	94	93	92	91	90	88	87	86	85	84	83
97	98	98	99	99	99	98	97	95	94	93	92	91	90	88	87	86	85	84
98	99	99	100	100	100	99	98	96	95	94	93	92	91	90	89	88	86	85
1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0659
Local Daylight Time				Local Daylight Time														

To estimate the FFMC during the afternoon or overnight, find the daily standard FFMC then move horizontally to the column that corresponds to the prediction time.

[1] Adapted from Lawson et al. (1996).

Table A.2 Diurnal FFMC Adjustments: 0600-1159 LST

Time LST	RH	Standard Daily FFMC																														
		50	60	70	72	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
0600	<38	64	67	62	63	64	65	65	66	67	68	69	69	70	71	72	73	74	75	76	78	79	80	81	83	84	85	87	88	90	92	93
	38-57	48	53	58	56	61	62	63	63	64	65	66	66	67	68	69	70	71	72	73	74	75	76	77	78	80	81	82	84	86	87	88
	>57	43	48	55	57	58	59	60	60	61	62	63	64	65	65	67	67	68	69	71	72	73	74	75	76	77	78	80	81	83	84	85
0700	<38	56	60	64	65	67	67	68	69	69	70	71	72	72	73	74	75	76	77	78	79	80	81	83	84	85	87	88	90	91	93	94
	38-77	49	54	60	61	63	63	64	65	66	67	67	68	69	70	71	72	73	74	75	76	77	78	79	81	82	83	84	86	87	88	90
	>77	44	49	56	57	59	60	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	77	78	79	81	82	83	85	86	88
0800	<48	59	63	67	68	69	70	70	71	72	72	73	74	75	75	76	77	78	79	80	81	83	83	84	86	86	88	89	90	92	93	95
	48-67	50	55	61	63	64	65	66	67	68	68	69	70	71	72	73	74	75	76	77	78	79	81	82	83	84	85	87	88	89	90	91
	>67	46	50	57	58	59	61	61	62	63	64	65	66	67	68	69	70	71	72	73	74	76	77	78	79	81	82	84	86	87	88	89
0900	<43	64	67	71	72	73	74	74	75	75	76	77	77	78	79	80	80	81	82	83	84	85	86	87	88	89	90	91	93	94	95	96
	43-62	56	60	66	67	69	69	70	71	72	72	73	74	75	76	77	77	78	79	80	81	82	83	85	86	87	88	89	91	92	93	94
	>62	51	56	62	63	64	65	66	66	67	68	69	70	70	71	72	73	74	75	76	77	78	79	80	82	83	84	85	87	88	90	91
1000	<38	70	72	76	77	77	78	78	79	79	80	81	81	82	82	83	84	85	85	86	87	88	89	90	91	92	93	94	96	96	97	98
	38-57	62	66	71	72	73	74	75	75	76	77	77	78	79	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	96	97
	>57	57	61	67	68	69	70	70	71	73	72	73	74	74	75	76	77	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92
1100	<38	76	79	80	81	82	82	83	84	84	85	85	86	86	87	87	88	89	89	90	90	91	91	92	92	93	93	94	95	96	97	98
	38-64	69	0	72	76	77	78	79	80	80	81	82	82	83	83	84	85	86	87	87	88	89	89	90	91	91	92	93	94	96	97	
	>64.5	64	68	73	73	74	75	76	76	77	77	78	79	79	80	80	81	81	82	82	83	84	84	85	86	86	87	88	89	91	92	
1159	<33	82	83	85	86	87	87	87	88	88	89	89	89	89	90	90	90	91	91	91	92	92	92	92	93	93	93	94	95	96	97	98
	33-52	77	79	82	83	84	84	84	85	85	86	86	86	87	87	88	88	89	89	89	90	90	90	90	91	91	91	92	93	94	96	97
	>52	72	75	78	79	80	80	81	81	81	82	82	82	83	83	83	83	84	84	84	85	85	85	86	86	86	86	87	88	89	90	92

To estimate the FFMC in the morning, find the previous day's standard FFMC, then move down to the time and relative humidity for the prediction time. If the RH is unknown use the highest value.

TABLE A.3 FFMC slope - aspect adjustments

	Ground Slope and Aspect															
	1 - 15 %				16 - 30 %				31 - 45 %				46 - 60 %			
Level	N	E	S	W	N	E	S	W	N	E	S	W	N	E	S	W
80	78	79	82	80	77	78	82	80	74	77	83	81	72	76	84	81
82	80	81	84	82	79	80	84	82	76	79	85	83	74	78	85	83
84	83	83	85	84	81	82	86	84	79	81	87	84	76	80	88	84
86	85	85	87	86	83	84	88	86	81	83	89	86	78	82	90	86
87	86	86	88	87	84	85	89	87	82	84	90	87	80	83	90	87
88	87	87	89	88	85	87	90	88	83	86	91	88	82	85	91	88
89	88	88	90	89	87	88	91	89	85	87	91	89	83	86	92	89
90	89	89	91	90	88	89	92	90	86	88	92	90	84	87	93	90
91	90	90	92	91	89	90	92	91	87	89	93	91	86	88	93	91
92	91	91	93	92	90	91	93	92	88	90	94	92	87	89	94	92
93	92	92	94	93	91	92	94	93	89	91	95	93	88	90	95	93
94	93	93	95	94	92	93	95	94	91	92	96	94	90	92	96	94

Determine the slope and aspect of the weather observation point, find FFMC, then move horizontally to the column that best describes the prediction point and read **adjusted FFMC** (from Alexander et al. 1984). These adjustments should be used with caution as they have not been rigourously tested. They should only be applied in slash and open fuel types on clear days in March, April, August, September or October between 1200 -2000 LST.

Table A 2 Diurnal FFMC Adjustments: 0600-1159 LST

TABLE A-1 FEMC slope - aspect adjustments

Appendix 6 Fire Behavior Prediction Worksheet Example

Fire No./Name SAMPLE		Date 29.04.95		Time 1600 LST	
Prediction Date & Time 30.04.95		From 1200 LST		To 1300 LST	
Prediction Point	1 PI	2 PI	3 APS	4 APS	5 PI
Fuel Type					
FBP System fuel type	C-4	M-1	D-1	S-2	[illegible]
Modifiers (CBH,C H,PDF,%Cured)		75%			35%
Fine Fuel Moisture Code					
Standard daily FFMC	93	94	88	94	94
Diurnal or Hourly FFMC	91	92	85	92	92
Ground slope (%)	0	15	10	50(15)	20(L)
Aspect	-	N	E	S(E)	W(L)
Adjusted FFMC	91	92	85	86	92
Initial Spread Index					
10 m wind speed (km/h)	25	15	-3	5	-15
Slope equiv wind speed (km/h)	-	5	3	26	8
Effective wind speed (km/h)	23	20	0	31	-7
ISI	16	16	2	41	8
BISI	2	2	2	-	4
Rate of Spread and Intensity					
BUI	100	25	60	100	NA
Equil. head fire ROS (m/min)	27	16	0.2	-	3
Back fire ROS (m/min)	2	2	0.2	-	9
Fire intensity class	6	5	2	6	3
Type of fire	C	I	S	S	S
Fire Size					
Elapsed time (min)	60	60	60	60	60
Head fire spread dist. (m)	1362	757	12	1980	1077
Back fire spread dist. (m)	101	50	-	-	462
Total spread dist. (m)	1462	807	12	1980	1539
Fire area (ha)	62	20			95
Perimeter length (m)	3360	1830			3400
Perimeter growth rate (m/min)	61	41			44
Remarks					

Appendix 6 Fire Behavior Prediction Worksheet Example

Fire No./Name SAMPLE		Date 29.04.95		Time 1600 LST	
Prediction Date & Time 30.04.95		From 1200 LST		To 1300 LST	
Prediction Point	1 PI	2 PI	3 APS	4 APS	5 PI
Fuel Type					
FBP System fuel type	C-4	M-1	D-1	S-2	O-1a
Modifiers (CBH,C.H,PDF,%Cured)		75%			95%
Fine Fuel Moisture Code					
Standard daily FFMC	93	94	88	94	94
Diurnal or Hourly FFMC	91	92	85	92	92
Ground slope (%)	0	15	10	50(15)	20(L)
Aspect	-	N	E	S(E)	W(L)
Adjusted FFMC	91	92	85	95	92
Initial Spread Index					
10 m wind speed (km/h)	23	15	-3	5	-15
Slope equiv wind speed (km/h)	-	5	3	26	8
Effective wind speed (km/h)	23	20	0	31	-7
ISI	16	16	2	41	8
BISI	2	2	2	-	4
Rate of Spread and Intensity					
BUI	100	25	60	100	NA
Equil. head fire ROS (m/min)	27	16	0.2	-	9
Back fire ROS (m/min)	2	2	0.2	-	9
Fire intensity class	6	5	2	6	5
Type of fire	C	I	S	S	S
Fire Size					
Elapsed time (min)	60	60	60	60	60
Head fire spread dist. (m)	1362	757	12	1980	1077
Back fire spread dist. (m)	101	50	-	-	462
Total spread dist. (m)	1462	807	12	1980	1539
Fire area (ha)	62	20			65
Perimeter length (m)	3350	1830			3400
Perimeter growth rate (m/min)	61	41			44
Remarks					

Appendix 6 Fire Behavior Prediction Worksheet

The attached worksheet may be used to record the input data required for the procedures in the section Use of the Guide and the resulting fire characteristics (see the sample worksheet).

1. Heading

Enter Fire Number and or Name; Date and Time; Prediction Date and Time Interval; Prediction Point. All calculations made on one sheet should be for the same time interval. Use a new sheet for each successive or new time interval. Use a separate prediction point for each different fuel type or slope/aspect class that is likely to be encountered during the prediction time interval. Specify the type of ignition at each prediction point: point ignition (P.I.) or active perimeter source (A.P.S.).

2. Fuel Type

Enter the Fuel Type Identifier which best represents the fuels at the prediction point. Also record any relevant modifiers (C-6 enter Crown Base Height; M-1 and M-2 enter Percent Softwood/Hardwood; M-3 and M-4 enter Percent Dead Fir; O-1 enter Percent Cured).

3. Fine Fuel Moisture Code

Enter the hourly FFMC for the Prediction Date/Time if known, or enter the Standard Daily FFMC for the Prediction Date and use it to determine the diurnal FFMC for the Prediction Time. Enter the Ground Slope (%) and Aspect (cardinal direction) for the area ahead of the Prediction Point, disregarding minor variations. If topographic adjustment is required, also record the slope and aspect of the weather observation point in brackets (use L for level): e.g. Ground slope 50 [15]; Aspect S [E]. Use these values to determine the Adjusted FFMC.

4. Initial Spread Index

Enter the 10 m open Wind Speed for the Prediction Time as a positive
e if the wind is blowing upslope, or a negative value if it is blowing
nslope. Enter the estimated values of Slope Equivalent Wind Speed,
ctive Wind Speed (Open WS + Slope Equivalent WS), ISI, and BISI.
ISI and BISI values are wind and slope adjusted.

5. Rate of Spread and Intensity

Enter BUI for the Prediction Date and record the Head Fire ROS, Back Fire ROS, Fire Intensity Class and Type of Fire from the tables. Record Type of Fire as S (surface fire), I (intermittent crown fire), or C (continuous crown fire).

6. Fire Size

Enter the Elapsed Time corresponding to the Prediction Time interval. Record the predicted Head fire Spread Dist., Back fire Spread Dist., Total Spread Dist. (Head fire + Back fire Spread Dists.), Fire Area, Perimeter Length, and Perimeter Growth Rate.

7. Remarks

Record any fire characteristics observed at the prediction time (Head fire ROS, Spread Dist., Type of Fire).

A blank form that may be reproduced is given on the next page.

FIRE BEHAVIOR PREDICTION

Fire No./Name		Date		Time	
Prediction Date & Time		From		To	
Prediction Point	1	2	3	4	5
Fuel Type					
FBP System fuel type					
Modifiers (CBH,C:H,PDF,%Cured)					
Fine Fuel Moisture Code					
Standard daily FFMC					
Diurnal or Hourly FFMC					
Ground slope (%)					
Aspect					
Adjusted FFMC					
Initial Spread Index					
10 m wind speed (km/h)					
Slope equiv wind speed (km/h)					
Effective wind speed (km/h)					
ISI					
BISI					
Rate of Spread and Intensity					
BUI					
Equil. head fire ROS (m/min)					
Back fire ROS (m/min)					
Fire intensity class					
Type of fire					
Fire Size					
Elapsed time (min)					
Head fire spread dist. (m)					
Back fire spread dist. (m)					
Total spread dist. (m)					
Fire area (ha)					
Perimeter length (m)					
Perimeter growth rate (m/min)					
Remarks					

FIRE BEHAVIOR PREDICTION

Fire No./Name		Date		Time	
Prediction Date & Time		From		To	
Prediction Point	1	2	3	4	5
Fuel Type					
FBP System fuel type					
Modifiers (CBH,C,H,PDF%Cured)					
Fine Fuel Moisture Code					
Standard daily FFMC					
Diurnal or Hourly FFMC					
Ground slope (%)					
Aspect					
Adjusted FFMC					
Initial Spread Index					
10 m wind speed (km/h)					
Slope equiv wind speed (km/h)					
Effective wind speed (km/h)					
ISI					
BISI					
Rate of Spread and Intensity					
BUI					
Equil. head fire ROS (m/min)					
Back fire ROS (m/min)					
Fire intensity class					
Type of fire					
Fire Size					
Elapsed time (min)					
Head fire spread dist. (m)					
Back fire spread dist. (m)					
Total spread dist. (m)					
Fire area (ha)					
Perimeter length (m)					
Perimeter growth rate (m/min)					
Remarks					

Probabilities of Sustained Ignition in Lodgepole Pine, Interior Douglas-fir, and White Spruce-Subalpine Fir Forest Types

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Canadian Forest Service
Natural Resources Canada
Victoria, B.C.

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FRDA Handbook
012

Partnership Agreement on Forest Resource Development: FRDA II

Canada BC

Introduction

Tables of sustained ignition probabilities are presented for four benchmark forest fuel types: dry- and moist-site lodgepole pine, white spruce-subalpine fir, and interior Douglas-fir. The look-up tables were derived from logistic regression equations that were fit to hundreds of small-scale match-fire and campfire observations made near Prince George and 100 Mile House, B.C. by Canadian Forest Service fire researchers. The field research studies were carried out in the 1950s and 1960s as part of the early development of the Canadian Forest Fire Danger Rating System, but the original data have been re-analyzed using current versions of components of the Canadian Forest Fire Weather Index System as predictors of ignition probability.

A complete scientific and technical description of the development of the lodgepole pine and spruce-subalpine fir equations is given in Lawson *et al.* (1994a), and is illustrated in a wall poster (Lawson *et al.* 1994b) as graphs with colour photos of the forest types. A computer application (Lawson *et al.* 1996) links these same equations with a new diurnal Fine Fuel Moisture Code program (Lawson, Armitage and Hoskins 1996). Derivation of the interior Douglas-fir equation is presented in the Appendix.

The following four equations are used to calculate the ignition probabilities presented in tables S1.1-S1.4:

Dry lodgepole pine

$$P = 1/ (1 + \exp(2.107 - 0.727 * ISI)) \quad \text{S1.1}$$

Moist lodgepole pine

$$P = 1/ (1 + \exp(2.146 - 0.009 * BUI - 0.349 * ISI)) \quad \text{S1.2}$$

White Spruce - subalpine fir

$$P = 1/ (1 + \exp(2.766 - 0.005 * DC - 0.396 * ISI)) \quad \text{S1.3}$$

Interior Douglas-fir

$$P = 1/ (1 + \exp(1.563 - 0.005 * BUI - 0.478 * ISI)) \quad \text{S1.4}$$

Probability of sustained ignition is not a standard output from the Canadian Forest Fire Behavior Prediction (FBP) System (Forestry Canada Fire Danger

Group 1992), but is included here as a supplement for the convenience of users. Potential uses include gauging the likelihood of fire starts or fire arrivals for preparedness planning of initial attack crew positioning and readiness, and judging spot-fire ignition potential for wildfires or prescribed fires. The ignition probabilities described here relate to the probability of an ignition from small fire brands, such as matches or camp fires persisting with flaming combustion (for at least 2 minutes for match fires and 15 minutes for campfires) and reaching the threshold condition for fire spread and growth. Camp fires were necessary for sustained ignition in the white spruce-subalpine fir forest type. Matches and camp fires were both potentially successful fire brands in the other forest types, depending on burning conditions.

Use of the Tables

The following steps form the procedure for using the Ignition Probability Tables (Table and Appendix numbers refer to Taylor *et al.* 1996).

1. Select the most appropriate forest type and/or variant from the four presented.

   Detailed forest type descriptions and a photograph accompany each ignition probability table. Ignition probability differences among variants within a single FBP System fuel type should be expected. The "dry" and "moist" lodgepole pine forest types can be considered variants of C-3 (Mature Jack or Lodgepole Pine). The interior Douglas-fir forest type should be considered a variant of C-7 (Ponderosa pine - Douglas-fir). The white spruce-subalpine fir forest type can be considered a variant of C-2 (Boreal spruce), as shown by DeGroot (1993).

2. Determine the most representative Fine Fuel Moisture Code (FFMC), 10-m open wind speed, and Initial Spread Index (ISI) for the time of interest.

   a) The hourly FFMC (Van Wagner 1977) should be used, if available. Alternatively, the diurnal FFMC (Tables A.1 - A.2, Appendix 5) may be used for any desired time of the day. The daily standard FFMC may be used to represent mid-afternoon (16:00 hr LST) conditions.

b) Wind speed at 10 m in the open should be measured, forecasted, or estimated from the Beaufort Scale (Appendix 4) for the time of interest.

c) For the "Dry" Lodgepole Pine forest type , enter Table S1.1 with FFMC and 10-m wind speed from 2a and 2b, above.

For other forest types and/or variants, determine the ISI using Table 3, with FFMC and 10-m open wind speed from 2a and 2b, above.

3. Determine the Buildup Index (BUI) or Drought Code (DC) from the nearest representative weather station, as required for a given forest type.

4. From the ignition probability table for the forest type of interest, find the probability-of-ignition value (%) at the intersection of the two required input values. Probability-of-ignition classes (low, medium, high) are differentially shaded in the body of each table.

References

De Groot, W.J. 1993. Examples of fuel types in the Canadian Forest Fire Behavior Prediction System. For. Can., Nor. For. Cent., Edmonton, Alta. Poster (with text).

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The authors thank Marty Alexander, Canadian Forest Service (CFS), Edmonton, for suggesting presentation of the logistic regression equations for probability of ignition as look-up tables to complement the existing poster/graph and computer applications, and for reviewing the manuscript. Steve Taylor, CFS, Victoria, and Judi Beck, British Columbia Forest Service Protection Program, also provided thorough and helpful reviews. Tim Lynham, CFS, Sault Ste. Marie, provided the computerized national data set from which the 100 Mile House data about interior Douglas-fir was extracted for analysis. University of Victoria Co-op students Jim Andrews and Robin Pike analyzed the data.

"Dry" lodgepole pine forest-type characteristics

* Pure, moderately dense stands of mature lodgepole pine;
* scattered pine understory;
* sandy well-drained soils, low-productivity sites dominated by feathermoss and *Cladina* (lichen); B.C. biogeoclimatic classification SBSmk1/03 is typical;
* forest floor shallow (3-5 cm), low bulk density; and
* fire-carrying fuels - lichen, bearberry *(Arctostaphylos uva-ursi)*, feathermoss *(Pleurozium schreberi; Dicranum* spp.), needle litter.

Table S1.1

"Dry" lodgepole pine forest type - probability of sustained ignition (%) and ignition class

	10-m Open Wind Speed (km/h)										
FFMC	0	5	10	15	20	25	30	35	40	45	≥50
70	16	18	21	24	30	38	49	63	79	91	97
72	17	19	21	26	32	40	53	68	82	93	98
74	17	19	23	27	34	44	57	73	87	95	99
76	18	21	24	30	38	49	64	79	91	97	99
78	19	23	27	34	44	58	73	87	95	99	100
80	22	26	32	41	54	69	84	94	98	100	100
82	26	32	40	52	68	82	93	98	100	100	100
84	32	40	53	68	83	93	98	100	100	100	100
86	41	54	69	84	94	98	100	100	100	100	100
88	56	71	85	95	99	100	100	100	100	100	100
90	73	87	95	99	100	100	100	100	100	100	100
92	88	96	99	100	100	100	100	100	100	100	100
94	97	99	100	100	100	100	100	100	100	100	100
96	99	100	100	100	100	100	100	100	100	100	100
≥98	100	100	100	100	100	100	100	100	100	100	100

Ignition Class	Probability %
LOW	0-49
MEDIUM	50-75
HIGH	76-100

"Moist" lodgepole pine forest-type characteristics

* Mixed, well-stocked stands of mature lodgepole pine-Douglas-fir;
* significant understory of lodgepole pine, trembling aspen, white spruce, and subalpine fir;
* moderately well-drained soils typically derived from unstratified glacial deposits, medium site productivity, *Cornus canadensis* (bunchberry), scattered *Cladina* (lichen), feather mosses, and *Vaccinium membraneceum* (black huckleberry); B.C. biogeoclimatic classification SBSmk1/05 is typical;
* forest floor shallow (3-5 cm), low bulk density; and
* fire-carrying fuels - feather moss, needle litter.

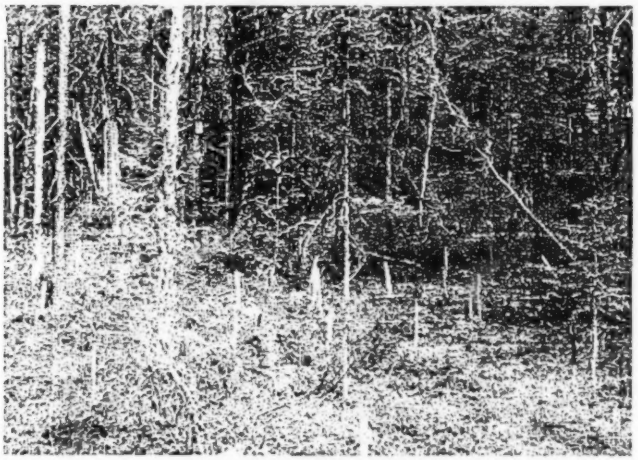

Table S1.2

"Moist" lodgepole pine forest type - probability of sustained igniton (%) and ignition class.

Buildup Index (BUI)

ISI	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
0.5	13	15	16	18	21	26	33	41
1	15	17	19	21	24	29	37	46
1.5	18	20	21	24	27	33	41	50
2	20	23	24	27	31	37	45	54
2.5	23	26	28	31	34	41	50	59
3	27	29	31	34	38	45	54	63
4	34	37	39	43	47	54	62	70
5	42	46	48	51	56	62	70	77
6	51	54	57	60	64	70	77	83
7	60	63	65	68	72	77	83	87
8	68	70	72	75	78	82	87	91
9	75	77	79	81	84	87	91	93
10	81	83	84	86	88	90	93	95
11	86	87	88	90	91	93	95	96
12	89	91	91	92	94	95	96	97
13	92	93	94	94	95	96	97	98
14	94	95	95	96	97	97	98	99
15	96	96	97	97	98	98	99	99
18	99	99	99	99	99	99	100	100

Ignition Class	Probability %
LOW	0-49
MEDIUM	50-75
HIGH	76-100

White spruce-subalpine fir forest-type characteristics

* Mixed, moderately dense stands of mature white (and/or Engelmann) spruce-subalpine fir, with scattered mature birch and Douglas-fir;
* significant understory of subalpine fir;
* soils range from loamy sands to sticky, poorly drained clays on moderately well-drained to imperfectly drained sites; herb and shrub layers dominated by *Aralia nudicaulis* (sarsaparilla), *Gymnocarpium dryopteris* (oak fern), *Vaccinium* (huckleberry) and *Cornus* (bunchberry) spp., *Oplopanax horridus* (devil's club) on wettest sites; mosses patchy; B.C. biogeoclimatic classification SBSmk1/07 (drier) and SBSmk1/08 (wetter) are typical;
* forest floors moderate to deep (6-12 cm), moderate to high bulk density; and
* fire-carrying fuels - litter, feather moss.

Table S1.3

White spruce - subalpine fir forest type - probability of sustained ignition (%) and ignition class

	Drought Code (DC)							
ISI	0 – 100	101 – 200	201 – 300	301 – 400	401 – 500	501 – 600	601 – 700	701 – 800
0.5	9	14	21	31	42	55	68	77
1	11	17	25	35	47	59	71	80
1.5	13	19	28	40	52	64	75	83
2	15	23	33	44	57	68	78	86
2.5	18	26	37	49	62	73	81	88
3	21	30	42	54	66	76	84	90
4	28	39	52	64	74	83	89	93
5	37	49	61	72	81	88	92	95
6	47	59	70	80	87	91	95	97
7	56	68	78	85	91	94	96	98
8	66	76	84	90	93	96	97	98
9	74	82	89	93	95	97	98	99
10	81	87	92	95	97	98	99	99
11	86	91	94	97	98	99	99	100
12	90	94	96	98	99	99	99	100
13	93	96	97	98	99	99	100	100
14	95	97	98	99	99	100	100	100
15	97	98	99	99	100	100	100	100
18	98	99	100	100	100	100	100	100

Ignition Class	Probability %
LOW	0-49
MEDIUM	50-75
HIGH	76-100

Interior Douglas-fir forest-type characteristics

- Well-stocked stands of interior Douglas-fir of varying age classes, including large, mature overstory trees with a significant understory;
- forest floor shallow (less than 3 cm); and
- fire-carrying fuels - grass covers the ground except under fir thickets, where needle litter and patchy moss predominates. Grass is assumed to be greater than 50% cured (dead), although the degree of curing is not a variable used in the ignition probability model.

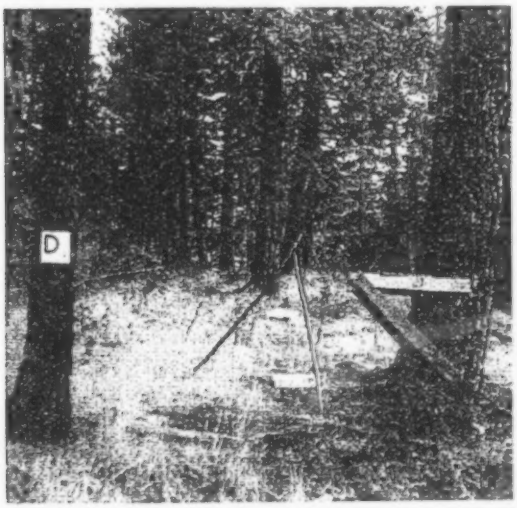

Table S1.4
Interior Douglas- fir - probability of sustained ignition (%) and ignition class

	Buildup Index (BUI)							
ISI	0 – 20	21 – 30	31 – 40	41 – 60	61 – 80	81 – 120	121 – 160	161 – 200
0.5	22	23	24	25	27	30	35	40
1	26	28	29	30	32	36	40	45
1.5	31	33	34	36	38	41	46	51
2	36	38	39	41	44	47	52	57
2.5	42	44	45	47	50	53	58	63
3	48	50	51	53	56	59	64	68
4	60	62	63	65	67	70	74	78
5	71	72	73	75	76	79	82	86
6	79	81	81	83	84	86	88	90
7	86	87	88	88	89	91	92	94
8	91	92	92	92	93	94	96	96
9	94	95	95	95	96	96	97	97
10	96	97	97	97	97	98	98	98
11	98	98	98	98	98	99	99	99
12	99	99	99	99	99	99	99	99
13	99	99	99	99	99	99	100	100
14	99	99	100	100	100	100	100	100
15	100	100	100	100	100	100	100	100

Ignition Class	Probability %
LOW	0-49
MEDIUM	50-75
HIGH	76-100

APPENDIX

Derivation of the Interior Douglas-fir Ignition Probability Table S1.4

Background

The equation for probability of sustained ignition used to produce Table S1.4 was derived from analysis of a data set collected during the years 1957-1959 near 100 Mile House, B.C. by Dr. P.M. Paul, now retired research scientist, Canadian Forest Service. The test-fire program there resulted in publication of the Cariboo, British Columbia, Forest Fire Danger Tables in 1965, while the study sites themselves were described in detail in annual progress reports,[1] which were used for decisions about data selection for the present analysis and for the site photograph.

The data for site BC-801 were obtained from a national data base on test fires conducted in Canada between 1931-1961 as part of a Canadian forest Service program of regional forest fire danger table development, which preceded the present national fire danger rating system. The test fire data base , consisting of some 20 000 fires, has been edited, merged with current version FWI System component values, and assembled in modern computer formats, as described by T. Lynham.[2]

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[1] Paul, P.M. 1957, 1958, 1959.Progress report on forest fire research, 100 Mile House, B.C., Can. For. Serv., For. Fire Res. Inst., File No. 668. Ottawa, Ont.

[2] Lynham, T.J. and D.L. Martell. 1989. Preliminary report on a national database of experimental fires in Canada. P41-44 in: Proc. National Workshop on forest fire occurrence prediction , May 3-4, 1989, Winnipeg, Man.

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Analysis of 100 Mile House data

Data analysis followed the same steps described by Lawson *et al.* (1994a). Two suitable study sites were chosen for characterization as "interior Douglas-fir" from the nine available; specifically, forest type "D-1, Fir-grass/ moss" (site code 80104) and "D-4, Fir- grass/ needle" (site 80107) (photo of D-4 included with Table S1.4). Site descriptions are included here as they were presented in Paul (1957):

> **Site D1** – Douglas-fir in varying age classes. Large mature fir predominates, but there is an abundance of older immature (81-120 years) with well-established young growth in understory... Intermingled with the grass, which is ubiquitous except under the trees, are patches of moss...
>
> **Site D4** – is located on the southwest slope of the ridge at a slightly lower elevation than D1, which occurs on a bench near the summit of the hill. It is well stocked, with the fir trees attaining a very good size, although smaller than the mature and overmature trees of D1. Young reproduction, up to 4 feet, is extensive, and there is a fairly complete ground cover of grass, although it is continuously broken by patches of fir needles.

Paul (1957, 1958, and 1959) reported progression of grass curing through the test-fire seasons. Curing started in late May 1957 as 75-80%, decreasing to 35- 45 % by mid- July, and increasing again during September to about 70 % by late September. However, in 1958 (a drier summer) grass was 75-85% cured by late August. Grass curing could not be analyzed as an independent variable in the model, but an assumption could be made that test fires were usually conducted when grass was 50% or more cured.

Before the test-fire data were analyzed for the two sites, diurnally adjusted FFMC and ISI were calculated for each test fire using the diurnal FFMC program from Lawson, Armitage and Hoskins (1996) and the noon 10-m open wind speed recorded at the headquarters weather station. A dependent binary variable, "ignition", was defined as "yes" if the burned area for match fires was more than 0.30 ft^2, and "no" if less than or equal to 0.30 ft^2 . This area criterion was chosen arbitrarily after inspecting the data and comparing them with results from a separate analysis on "vigor" class (on file, Pacific Forestry Centre). While the burned-area threshold for successful ignition

was larger than the 0.05 ft^2 used by Lawson *et al.* (1994a) for lodgepole pine match fires, the interior Douglas-fir forest types were faster spreading, being grass dominated.

Logistic regression was used to develop a preliminary model of "ignition" as predicted from diurnally adjusted FFMC, DMC, DC, ISI, and BUI. A total of 391 match fires (no camp fires) were available from sites D-1 and D-4 combined, with all D-1 fires recording an area greater than 0, while 80% of D-4 fires burned an area greater than 0.

A logistic regression equation that included ISI and BUI produced the statistically best results from the two independent variables (adding DMC increased the r^2 and total correct statistics slightly). The equation for probability of sustained ignition in interior Douglas-fir is

$$P = 1/(1 + \exp(1.563 - 0.005 * BUI - 0.478\ ISI))$$

The equation is plotted in three dimensions in Figure 1, and Table 1 summarizes the observed and expected outcomes by decile and overall goodness-of-fit.

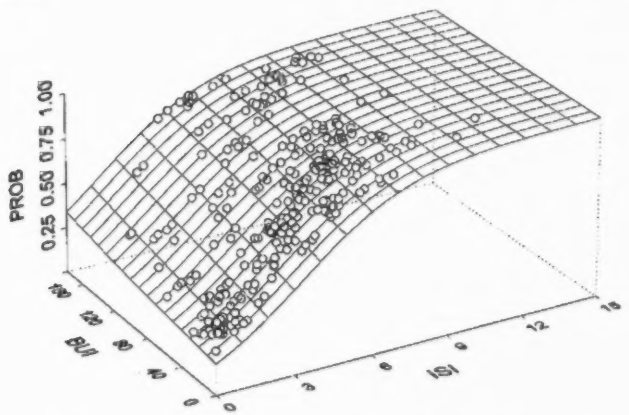

Figure 1. Probability of sustained ignition vs. Initial Spread Index (ISI) and Buildup Index (BUI) for interior Douglas-fir forest type. Plotted points represent test fires from sites D1 and D4, 100 Mile House, B.C.

Table 1. Logistic regression statistics: observed and expected outcomes by decile, overall goodness-of-fit, and success of prediction by the model, interior Douglas-fir forest type.

P	P	Total	Ignition		No Ignition		χ^2	P-value	R^2
Upper Limit	Avg.	Fires	Obs.	Exp	Obs.	Exp	(8 df)		
0.307	0.262	38	13	10.0	25	28.0			
0.414	0.350	39	17	13.7	22	25.3			
0.589	0.509	40	16	20.4	24	19.6			
0.657	0.616	39	18	24.0	21	15.0			
0.743	0.704	39	27	27.5	12	11.5			
0.790	0.766	38	29	29.1	9	8.9			
0/843	0.820	40	36	32.8	4	7.2			
0.883	0.860	39	36	33.5	3	5.5			
0.923	0.902	38	35	34.3	3	3.7			
1.000	0.947	41	37	38.8	4	2.2			
		391					13.1	0.106	0.189

Success of prediction by the model

	Ignition Predicted	No Ignition Predicted	Total
Ignition	197.6	66.4	264
No Ignition	66.4	60.6	127
Predicted Total	264.0	127.0	391
Proportion Correct	0.749	0.477	
Total Correct	0.661		
Success Index	0.073	0.153	